fresh marshes (Anahuac National Wildlife Refuge, Brazoria National Wildlife Refuge, and Trinity River Delta). Elevations were measured to the nearest 0.5 cm (2 inches) and distances were measured to the nearest meter. Compass bearings of the transects were also recorded.

County soil surveys (Brazoria, Chambers, Galveston, and Harris Counties) were used to define and characterize soils at the various field check sites. Information obtained from the soil surveys included soil type, salinity, drainage, frequency of flooding, position of water table, and prevalent vegetation.

The locations of field survey sites were plotted on aerial photographs, and later accurately transferred to USGS 7.5-minute quadrangle topographic maps using a Zoom Transfer Scope where necessary. Universal Transverse Mercator (UTM) coordinates were determined for each site and these data were entered into computer data management systems, including the geographic information system, ARC-INFO.

WETLAND COMMUNITIES IN THE GALVESTON BAY AREA

General Setting of the Galveston Bay System

The geologic framework of the Galveston Bay area consists of Modern-Holocene and Pleistocene systems including the modern wetland, or marsh and marsh-swamp systems (fig. 2). The geomorphic features on which the various types of coastal wetlands have developed are the result of numerous interacting processes. Physical processes that influence wetlands include rainfall, runoff, fluctuations in the water table, streamflow, evapotranspiration, waves and longshore currents, astronomical and wind tides, storms and hurricanes, deposition and erosion, subsidence, faulting, and sea-level rise (table 1). These processes have contributed to the development of a gradational array of permanently inundated to infrequently inundated environments ranging in elevation from the submerged lands of the estuarine system through the topographically higher wetland system, which grades upward from the astronomical-tidal zone through the wind-tidal zone to the storm-tidal zone.

Exchange of marine waters with bay-estuary-lagoon waters in the Galveston Bay system occurs primarily through two major tidal inlets: Bolivar Roads at the north end of Galveston Island and San Luis Pass at its south end (fig. 1). Additional exchange occurs at Rollover Pass, a narrow dredged channel at the east end of Bolivar Peninsula. The predominant sources of fresh-water inflow are the Trinity and San Jacinto Rivers (fig. 1). Salinities in the Galveston Bay system are generally highest in West and Christmas Bays where mean salinities are typically above 20 parts per thousand (ppt) and may range into the 30's. These salinities are in marked contrast to Trinity Bay, where Trinity River fresh-water inflows have a moderating influence; mean monthly salinities in Trinity Bay are usually less than 15 ppt and occasionally are below 5 ppt (Pulich and White, 1991).

These numerous interacting processes in the Galveston Bay system have a major bearing on the location and composition of wetland plant communities.

Classification of Wetland Communities: Background and Previous Studies

Classification of wetland communities ranges from broad, general systems in which the entire coastal wetland system is encompassed within a single unit (usually as part of a statewide vegetation classification), to the more detailed classifications that focus specifically on coastal

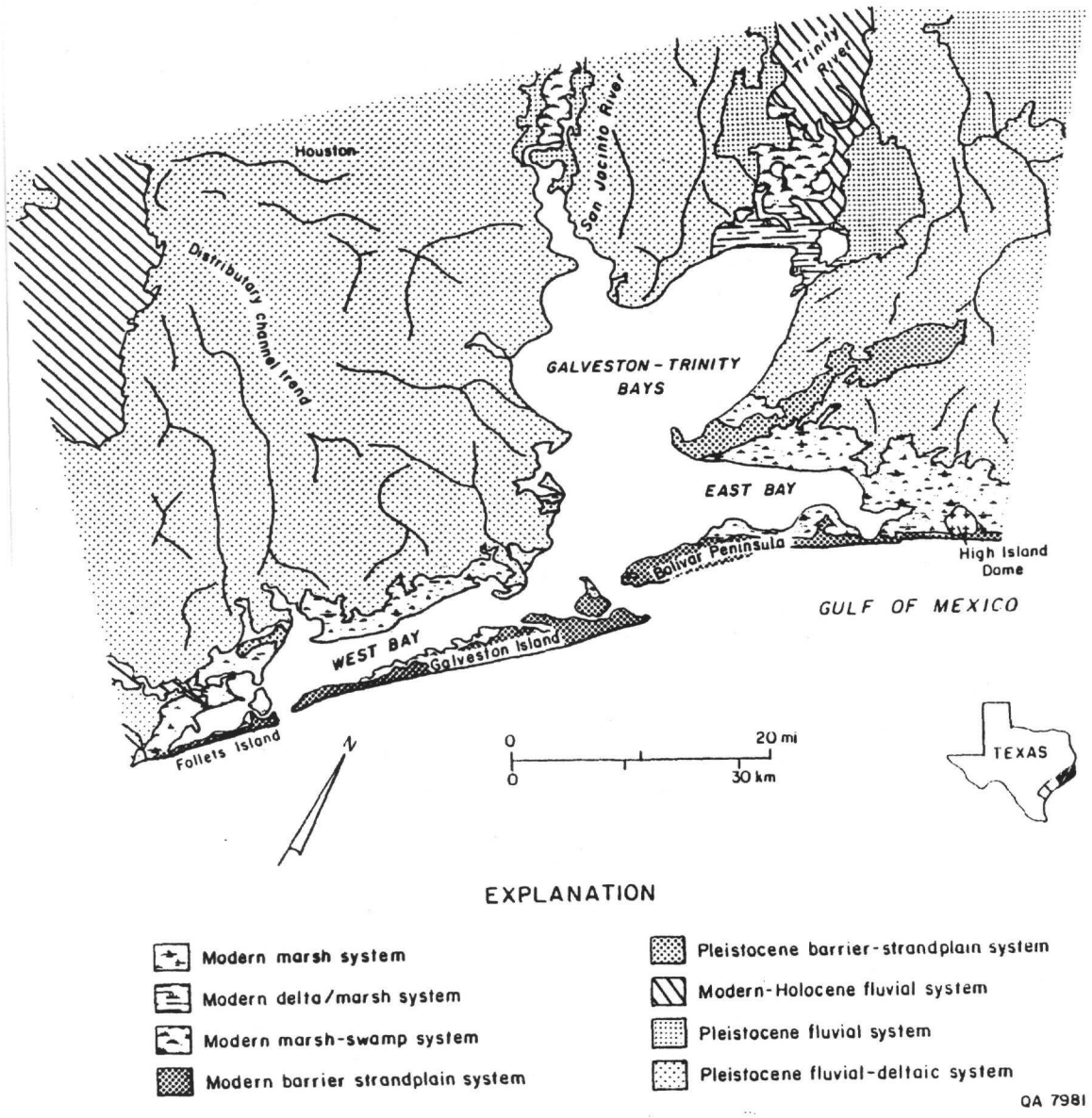


Figure 2. Natural systems in the Galveston Bay area. (From Fisher and others, 1972, 1973)

Table 1. Generalized characteristics of active coastal processes and conditions in the Galveston Bay area. (From White and others, 1985)

Climatic zone:	Humid *(Thornthwaite, 1948)*
Average annual precipitation:	41.8 to 51.5 inches/yr (106.2 to 130.8 cm/yr) *(Fisher and others, 1972)*
Dominant wind directions:	Southeasterly, northerly *(Fisher and others, 1972)*
Average wind speed (in 1978 at Texas City):	6.8 knots (12.6 km/hr) *(Shew and others, 1981)*
Astronomical tidal range: Gulf shoreline (Galveston Pleasure Pier) Mean diurnal: Bay shoreline (mean):	 2.1 ft (0.6 m) *(U.S. Department of Commerce, 1978)* 0.5 to 1.4 ft (0.2 to 0.4 m) *(Diener, 1975)*
Tidal current velocities: Bolivar Roads Average maximum flood: Average maximum ebb:	 3.3 knots (1.7 m/sec) *(Bernard and others, 1959)* 4.3 knots (2.2 m/sec) *(Bernard and others, 1959)*
Wave height (Gulf): (Caplan, Texas) Onshore wave height:	 Between 2.5 and 3.5 ft (0.8 and 1.1 m) about 65% of the time, *(U.S. Army Corps of Engineers, 1956)*
Direction of net longshore sediment transport:	Southwesterly *(Fisher and others, 1972)*
Maximum hurricane surge height on open coast:	12.7 ft (3.9 m) above MSL *(Bodine, 1969)*
Hurricane frequency:	12% in any one year *(Simpson and Lawrence, 1971)*
Gulf shoreline change, Bolivar Roads to San Luis Pass from 1850-52 to 1973-74:	Total gain from accretion of 1,074 acres and loss from erosion of 1,183 acres; net loss of 109 acres *(Morton, 1977)*
Subsidence: Pasadena - Houston Ship Channel area:	 8.5 to 9 ft (2.6 to 2.7 m) during 1906-1973 *(Ratzlaff, 1980)*
Faulting: Houston metropolitan area:	 Offset by at least 160 faults *(Verbeek and Clanton, 1981)*

wetlands and subdivide them into several units. Among the broad descriptive systems are: Bray's (1906) Salt Marsh Meadows; Tharp (1926) and Godfrey and others' (1973) Coastal Marsh; Kuchler's (1966) Southern Cordgrass Prairie; Thomas (1975) and Gould's (1975) Gulf Prairies and Marshes; and Frye and others' (1984) Marsh/Barrier Island.

Among the more specific descriptions of wetland communities, which include a classification scheme and/or which focus on a significant part of the upper (north and central) Texas Coast including the Galveston Bay area, are those by Shaw and Fredine (1956), Fisher and others (1972, 1973), Diener (1975), Lazarine (n.d.), Fleetwood (n.d.), Harcombe and Neaville (1977), Adams and Tingley (1977), Benton and others (1979), Cowardin and others (1979), Gosselink and others (1979), Ward and Armstrong (1980), Shew and others (1981), Thayer and Ustach (1981), and White and others (1985 and 1987).

Most classifications have subdivisions based on salinities because the community composition of coastal wetlands is influenced by the proximity of saline and brackish waters of the marine and estuarine systems. Bray (1906) listed his Salt Marsh Meadow under a more general heading of Salt Water Vegetation. Although Tharp's (1926) coastal marsh unit was not subdivided according to salinities, he did note that giant reed (*Arundo donax*), common reed (*Phragmites australis*), and marshmillet, or southern wildrice (*Zizaniopsis miliacea*) are abundant along streams and other "semi-fresh water bodies." Shaw and Fredine (1956) used two major subdivisions in coastal areas: coastal saline areas and coastal fresh areas. Fisher and others (1972, 1973) subdivided marshes on the basis of salinities into salt-water, brackish (closed), brackish- to fresh-water, and inland fresh-water marshes. Lazarine (n.d.) in a field reference guide to common wetland plants subdivided wetland types into saline, brackish, and fresh. Gosselink and others (1979) followed Chabreck (1972) by subdividing marshes into four categories in order of decreasing salinities: saline, brackish, intermediate, and fresh (for mapping and discussion purposes, intermediate was combined with brackish). Harcombe and Neaville (1977), in describing and mapping wetlands in Chambers County, used brackish and fresh subdivisions (table 2) (salt marshes were not included because of their absence or limited areal extent). Fleetwood (n.d.) in a study of vegetation in the Brazoria Wildlife Refuge, recognized (in addition to fresh marsh) saline, brackish, and intermediate components of the marsh system, but because of "dynamic wet and dry cycle conditions" combined them into a single unit designated as salt marsh (table 3). Among the major subdivisions (systems) used by Cowardin and others (1979) are estuarine and palustrine, which in simplified terms correspond with saline-brackish and fresh marsh areas, respectively, when classifying emergent wetlands. (In coastal tidal areas, palustrine wetlands begin where salinity, due to ocean-derived salts, is below 0.5 ppt; it should be noted that salinity modifiers can be used in both the estuarine and palustrine systems so the palustrine system can have salt marshes in areas where the salts are not ocean derived.) White and others (1985) used three basic categories: salt-, brackish-, and fresh-water marshes (table 4). Saline flats and marshes were among major vegetational areas defined by Brown (1985) for southeastern Harris County (table 5). Harcombe and Neaville (1977), Fleetwood (n.d.), and Brown (1985) have compiled detailed checklists of plants, including wetland species, occurring in Chambers, Brazoria, and Harris Counties.

In addition to subdivision based on relative salinities, some classifications subdivide marsh communities on the basis of inundation frequency determined in large part by elevation with respect to mean sea level. In coastal areas where the range in astronomical (lunar) tides is high, such as along the Atlantic Coast, the salt-marsh community is commonly subdivided into distinct low and high marshes. Broad areas are flooded on a regular (daily) basis, and plants like smooth cordgrass (*Spartina alterniflora*) that live in the intertidal zone represent extensive areas of low marshlands that are readily distinguished from high, irregularly flooded marshes. However, along the Texas coast astronomical tidal ranges are low and, thus, areas flooded on a daily basis, although dominated by smooth cordgrass, are much more restricted in areal extent. Wind-driven tides have a dominant influence along the Texas coast because they flood more extensive areas.

Table 2. Dominant and common plants in brackish and fresh marshes in Chambers County. (From Harcombe and Neaville, 1977)

Brackish Marsh

Dominated by:

Spartina patens (marsh-hay or saltmeadow cordgrass)

Distichlis spicata (seashore saltgrass)

Isolated clumps of:

Scirpus maritimus (saltmarsh bulrush)

Scirpus olneyi (Olney bulrush)

Near tidal drains:

Juncus roemerianus (needlegrass rush)

Common on levees:

Phragmites australis (common reed)

Spartina cynosuroides (big cordgrass)

Common in fresher areas:

Paspalum vaginatum (seashore paspalum)

Paspalum lividum (longtom)

Common locally:

Spartina alterniflora (smooth cordgrass)

Fresh Marsh

Phragmites australis (common reed)

Cladium jamaicense (sawgrass)

Zizaniopsis miliacea (cutgrass)

Panicum repens (torpedograss)

Paspalum lividum (longtom)

Typha latifolia and *T. domingensis* (cattail)

Spartina cynosuroides (big cordgrass)

Alternanthera philoxeroides (alligator weed)

Table 3. Common species in salt and fresh marshes in the Brazoria National Wildlife Refuge. (From Fleetwood, n.d.)

Salt Marsh

Dominants:

Spartina patens (marshhay cordgrass)

Distichlis spicata (seashore saltgrass)

In fresher areas:

Paspalum vaginatum (seashore paspalum)

Scirpus olneyi (Olney bulrush)

Scirpus americanus (American bulrush)

Other common species:

Phragmites australis (common reed)

Paspalum lividum (longtom)

Aster subulatus (saltmarsh aster)

Agalinis maritima (seaside gerardia)

Salt Flats and Salt Barrens

Monanthochloe littoralis (shoregrass)

Batis maritima (saltwort)

Lycium carolinianum (Carolina wolfberry)

Borrichia frutescens (sea-oxeye)

Salicornia virginica (perennial glasswort)

Fresh Marsh

Scirpus californicus (California bulrush)

Paspalum lividum (longtom)

Leptochloa uninervia (Mexican spangletop)

Echinochloa crusgalli (barnyard grass)

Pulchea purpurascens (purple pluchea)

Pistia stratiotus (water-lettuce)

Echinodorus cordifolius (burhead)

Saggitaria graminea (grassy arrowhead)

Table 4. Typical plants found in grassflats, marshes, and transitional areas in the Galveston Bay area. (From White and others, 1985)

Unit	Scientific Name	Common Name
GRASS-FLAT (subaqueous marine grasses)	*Halodule beaudettei*	shoalgrass
	Ruppia maritima	widgeongrass
SALT-WATER MARSH	*Spartina alterniflora*	smooth cordgrass
	Batis maritima	saltwort
	Salicornia virginica	glasswort
	Salicornia bigelovii	glasswort
	Distichlis spicata	seashore saltgrass
	Borrichia frutescens	sea-oxeye
	Monanthochloe littoralis	shoregrass
	Juncus roemerianus	needle rush
	Suaeda sp.	seablite or seepweed
	Lycium carolinianum	Carolina wolfberry
	Spartina spartinae	gulf cordgrass
	Spartina patens	marshhay cordgrass
	Iva frutescens	bigleaf sumpweed
	Iva angustifolia	narrowleaf sumpweed
	Limonium nashii	sea-lavender
	Scirpus maritimus	salt-marsh bulrush
	Sporobolus spp.	dropseed
	Sesuvium portulacastrum	sea purslane
	Heliotropium curassavicum	salt heliotrope
BRACKISH-WATER MARSH	*Spartina spartinae*	gulf cordgrass
	Spartina patens	marshhay cordgrass
	Borrichia frutescens	sea-oxeye
	Distichlis spicata	seashore saltgrass
	Monanthochloe littoralis	shoregrass
	Scirpus maritimus	salt marsh bulrush
	Scirpus americanus	three-square bulrush
	Scirpus californicus	California bulrush
	Scirpus olneyi	Olney bulrush
	Alternanthera philoxeroides	alligatorweed
	Typha domingensis	narrowleaf cattail
	Typha latifolia	common cattail
	Spartina cynosuroides	big cordgrass
	Phragmites australis	common reed
	Eleocharis parvula	dwarf spikerush
	Eleocharis spp.	spikerush
	Cyperus spp.	flatsedge
	Echinochloa crusgalli	barnyard grass
	Leptochloa spp.	sprangletop
	Bacopa monnieri	coastal waterhyssop
	Aster tenuifolius	saline aster
	Aster subulatus	saltmarsh aster
	Aster spinosus	spiny aster
	Paspalum lividum	longtom
	Paspalum vaginatum	seashore paspalum
	Setaria geniculata	knotroot bristlegrass
	Zizaniopsis miliacea	giant cutgrass
	Solidago sempervirens	seaside goldenrod
	Baccharis halimifolia	groundsel bush
	Iva frutescens	bigleaf sumpweed
	Iva angustifolia	narrowleaf sumpweed
	Iva annua	seacoast sumpweed
	Sesuvium portulacastrum	sea purslane
	Salicornia spp.	glasswort
	Limonium nashii	sea-lavender

Unit	Scientific Name	Common Name
BRACKISH-WATER MARSH (cont.)	*Juncus roemerianus*	needle rush
	Lycium carolinianum	Carolina wolfberry
	Sporobolus spp.	dropseed
	Fimbristylis castanea	fimbry
	Hydrocotyle spp.	pennywort
FRESH-WATER MARSH	*Spartina spartinae*	gulf cordgrass
	Typha latifolia	common cattail
	Typha domingensis	narrowleaf cattail
	Scirpus americanus	three-square bulrush
	Scirpus californicus	California bulrush
	Paspalum lividum	longtom
	Eleocharis spp.	spikesedge
	Cyperus spp.	flatsedge
	Alternanthera philoxeroides	alligatorweed
	Juncus spp.	rush
	Ludwigia spp.	seedbox
	Sagittaria spp.	arrowhead
	Pontederia sp.	pickerelweed
	Polygonum spp.	knotweed
	Phragmites australis	common reed
	Bacopa monnieri	waterhyssop
	Echinodorus spp.	burrhead
	Eichhornia crassipes	water hyacinth
	Rhynchospora spp.	beakrush
	Fimbristylis spp.	fimbry
	Echinochloa crusgalli	barnyard grass
	Leptochloa spp.	sprangletop
	Spartina patens	marshhay cordgrass
	Lemna spp.	duckweed
	Hydrocotyle spp.	marsh pennywort
	Zizaniopsis miliacea	southern wildrice
	Sesbania drummondii	rattlebush
	Baccharis halimifolia	groundsel bush
	Cephalanthus occidentalis	buttonbush
	Salix nigra	black willow
TRANSITIONAL AREAS	*Spartina spartinae*	gulf cordgrass
	Cynodon dactylon	bermudagrass
	Borrichia frutescens	sea-oxeye
	Aster spinosus	spiny aster
	Paspalum monostachyum	gulfdune paspalum
	Paspalum lividum	longtom
	Panicum spp.	panicum
	Rynchospora spp.	beakrush
	Andropogon virginicus	broomsedge bluestem
	Andropogon glomeratus	bushy bluestem
	Iva annua	seacoast sumpweed
	Aristida spp.	threeawn
	Setaria spp.	bristlegrass
	Helianthus spp.	sunflower
	Sorghum halepense	johnsongrass
	Cassia fasciculata	partridge pea
	Cyperus spp.	flatsedge
	Eleocharis	spikerush
	Scirpus spp.	bulrush
	Croton spp.	doveweed
	Spartina patens	marshhay cordgrass
	Baccharis halimifolia	groundsel bush
	Sesbania drummondii	rattlebush

Table 5. Typical plants identified at saline sites at Armand Bayou and Vicinity. (From Brown, 1985)

Plant Name	Common Name
Panicum repens	torpedograss
Phragmites australis	common reed
Spartina, all species	cordgrasses
Sporobolus virginicus	seashore dropseed
Scirpus americanus	American bulrush
Scirpus maritimus	saltmarsh bulrush
Juncus roemerianus	needlegrass rush
Atriplex arenaria	saltbush
Salicornia bigelovii	annual glasswort
Suaeda linearis	annual seepweed
Sesuvium portulacastrum	sea-purslane
Opuntia lindheimeri	Texas pricklypear
Limonium nashii	sea-lavender
Sabatia arenicola	sand rosegentian
Cuscuta indecora	showy dodder
Ipomoea sagittata	saltmarsh morning glory
Heliotropium curassavicum	seaside heliotrope
Lycium carolinianum	Carolina wolfberry
Bacopa monnieri	coastal waterhyssop
Aster tenuifolius	perennial saltmarsh aster
Borrichia frutescens	sea oxeye
Iva frutescens	big-leaf sumpweed
Machaeranthera phyllocephala	camphor daisy

Although the periodicity of inundations is irregular, wind tides have developed a relatively broad low marsh that includes species other than regularly flooded *Spartina alterniflora*. Above this level are higher marshes that are flooded less frequently.

Shaw and Fredine (1956) define a regularly flooded salt marsh and an irregularly flooded salt marsh. Cowardin and others (1979) used water-regime modifiers to denote the regularity of flooding (table 6). White and others (1985) used the terms proximal and distal (for salt-water marshes) to differentiate areas that are more frequently flooded because of lower elevations and proximity to estuarine water from those areas less frequently flooded because of higher elevations and distal locations with respect to estuarine water.

Species Composition of Wetland Plant Communities, Galveston Bay System

To collect information on plant composition, wetland communities were surveyed at more than 150 sites around the Galveston Bay system; more than 135 sites are shown in figure 3, and are listed in appendices A and B. The Galveston Bay project area is defined by 30 USGS 7.5-minute quadrangle maps, although one additional map (Freeport) was included for the field surveys. The maps were assigned numbers from 1 to 31 to simplify numerical designations of the surveyed sites (fig. 4, table 7). Species composition at the various sites along with very brief descriptive notes on the relationship of the identified plant communities to topography (for example, high versus low zones) and local geographic features (such as roads or streams) are presented in appendix B.

Wetland plant communities in the Galveston Bay system include high and low categories of salt, brackish, and fresh marshes, and forested wetlands. Other environments include mud and sand flats, beaches and bars, submerged vascular vegetation, disturbed areas, and open water.

The most widely distributed wetland environments in the Galveston Bay system are marshes, the most extensive of which are brackish. Brackish marshes, as mapped by White and others (1985), compose roughly 65 to 70 percent of the marsh system in the Galveston Bay project area. Salt marshes are a distant second, composing roughly 25 to 30 percent. Fresh marshes make up the remaining 5 to 10 percent of the marsh system. Because many species can tolerate varying salinity regimes as well as water regimes, there is considerable overlap in the species composition of these marsh systems (table 8). The divergent plant communities in the project area are exemplified by the fresh marshes and swamps along the Trinity River which contrast sharply with the salt marshes that fringe Christmas Bay.

Because of the predominance of brackish and salt marshes in the project area, more than 60 percent of the field surveys were located in these marshes. Surveys of other environments ranged from approximately 8 percent in forested wetlands to about 5 percent in transitional areas (appendix A). With reference to all sites visited, the 15 most frequently encountered species, were headed by *Spartina patens* (marshhay or saltmeadow cordgrass) and *Distichlis spicata* (saltgrass) (table 9).

Each of the species in table 9 was observed at more than 20 sites, *Spartina patens* and *Distichlis spicata* occurred at more than 60 sites, and *Spartina alterniflora* (smooth cordgrass) at more than 40 sites. Other species listed as among the top 25 reported include *Solidago* spp., *Limonium nashii, Phragmites australis, Lycium carolinianum, Paspalum vaginatum,* and *Suaeda linearis.* These species plus those listed in table 9 are typical of the brackish and salt marsh systems.

Table 6. Water regime descriptions for wetlands used in the Cowardin and others (1979) classification system.

Nontidal

(A)	Temporarily flooded—Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Plants that grow both in uplands and wetlands are characteristic of this water regime.
(C)	Seasonally flooded—Surface water is present for extended periods, especially early in the growing season, but is absent by the end of the growing season in most years. The water table is extremely variable after flooding ceases, extending from saturated to well below the ground surface.
(F)	Semipermanently flooded—Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land's surface.
(H)	Permanently flooded—Water covers land surface throughout the year in all years.

Tidal

(L)	Subtidal—The substrate is permanently flooded with tidal water.
(M)	Irregularly exposed—The land surface is exposed by tides less often than daily.
(N)	Regularly flooded—Tidal water alternately floods and exposes the land surface at least once daily.
(P)	Irregularly flooded—Tidal water floods the land surface less often than daily.
(S)*	Temporarily flooded—Tidal
(R)*	Seasonally flooded—Tidal
(T)*	Semipermanently flooded—Tidal
(V)*	Permanently flooded—Tidal

*These water regimes are only used in tidally influenced, freshwater systems.

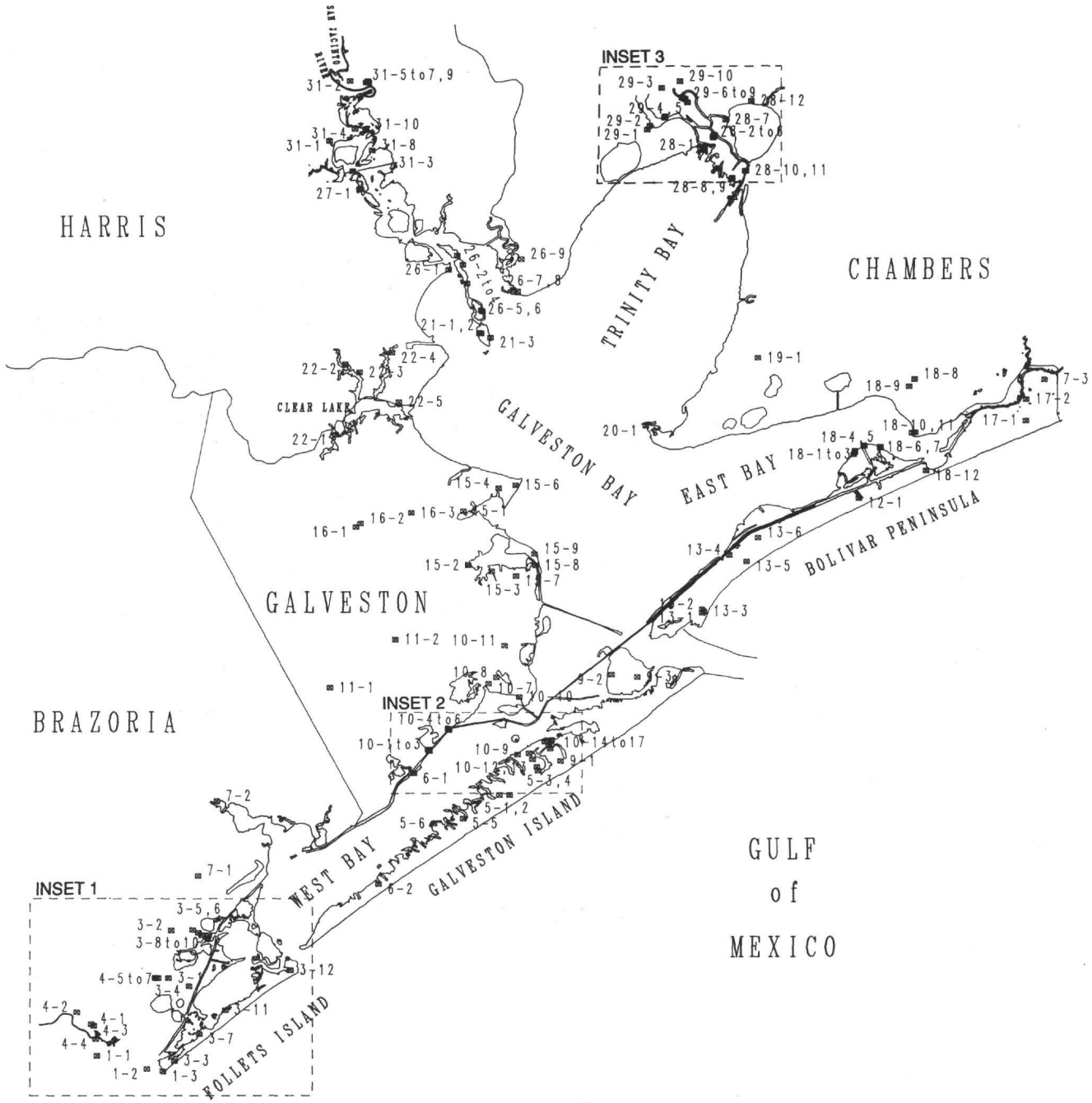
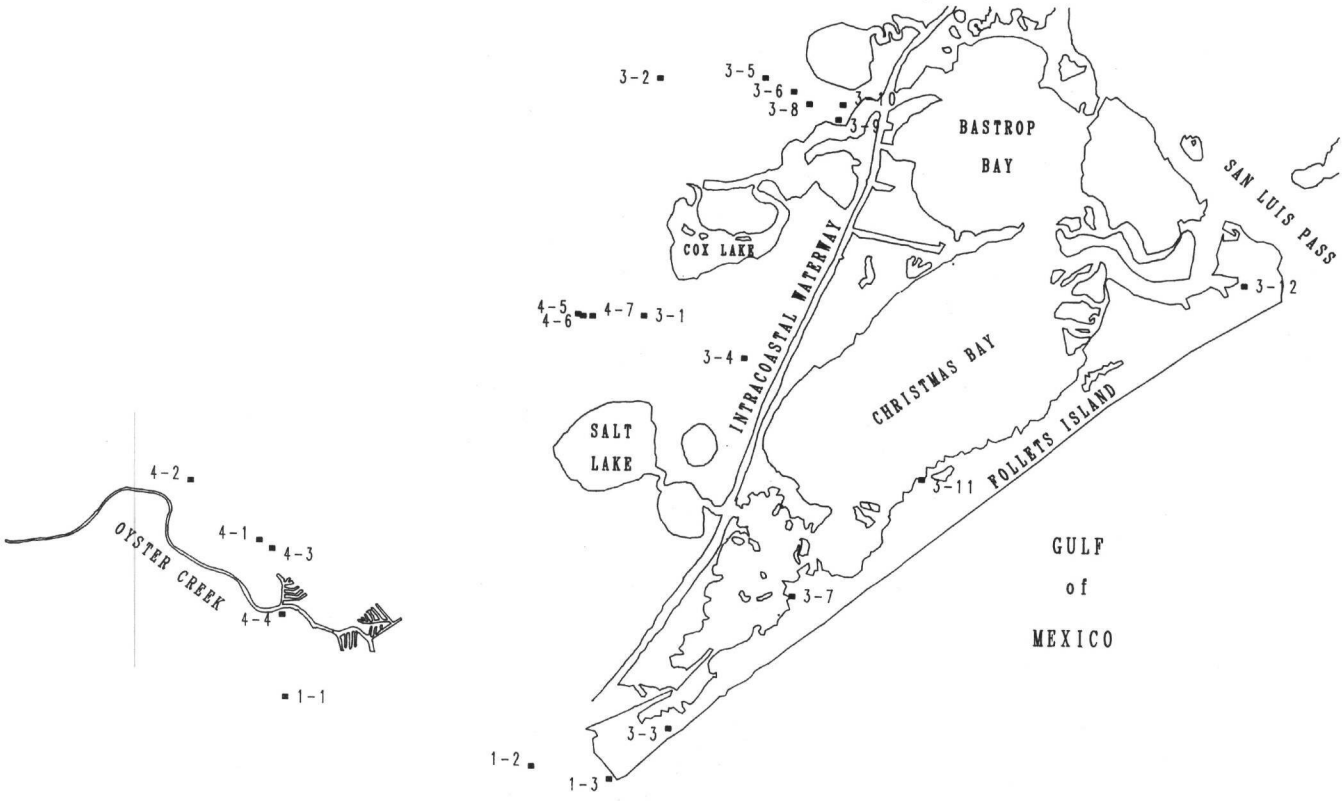
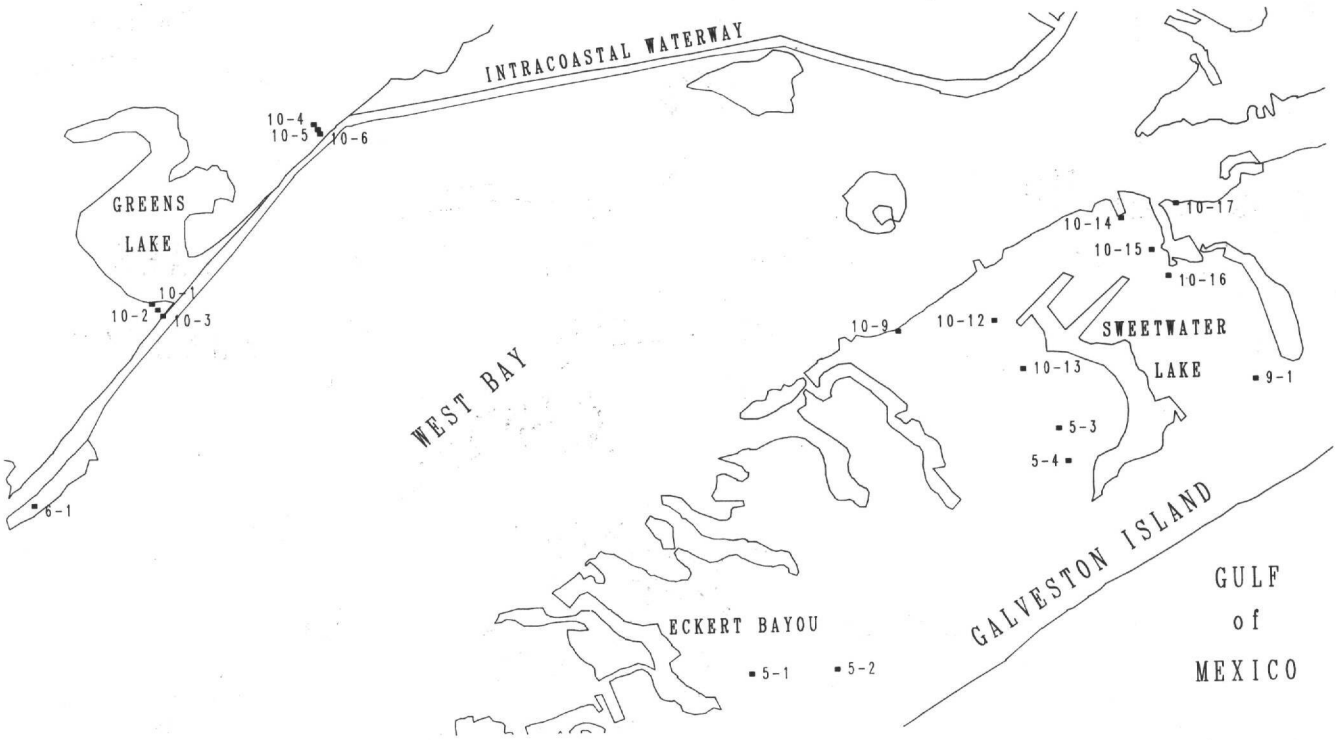


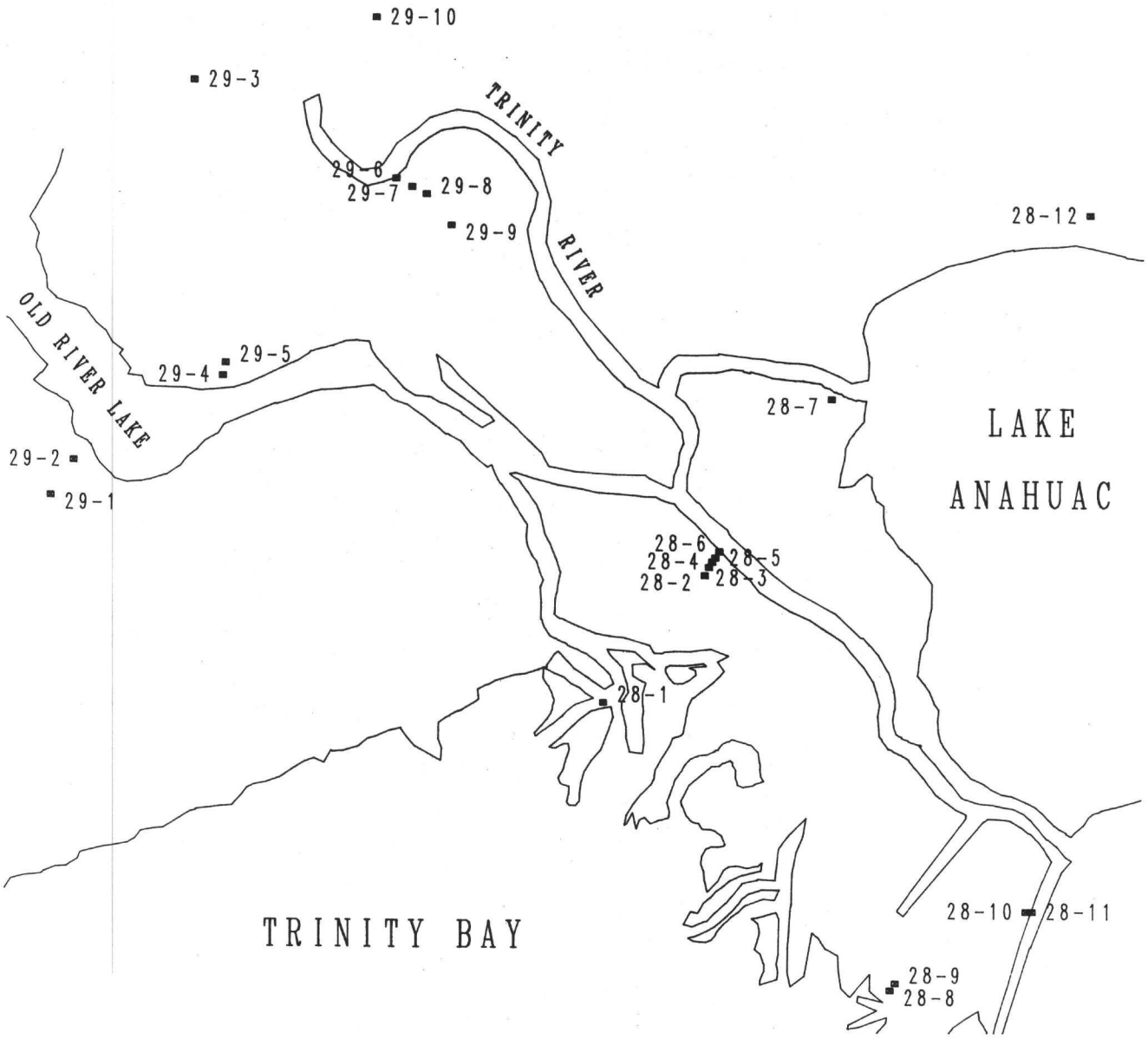
Figure 3. Location map of field survey sites. Inset maps are shown on figures 3a, b and c. See figure 4 and table 7 for identification of quadrangle maps on which sites are located.



(a) Inset 1 from figure 3.



(b) Inset 2 from figure 3.



(c) Inset 3 from figure 3.

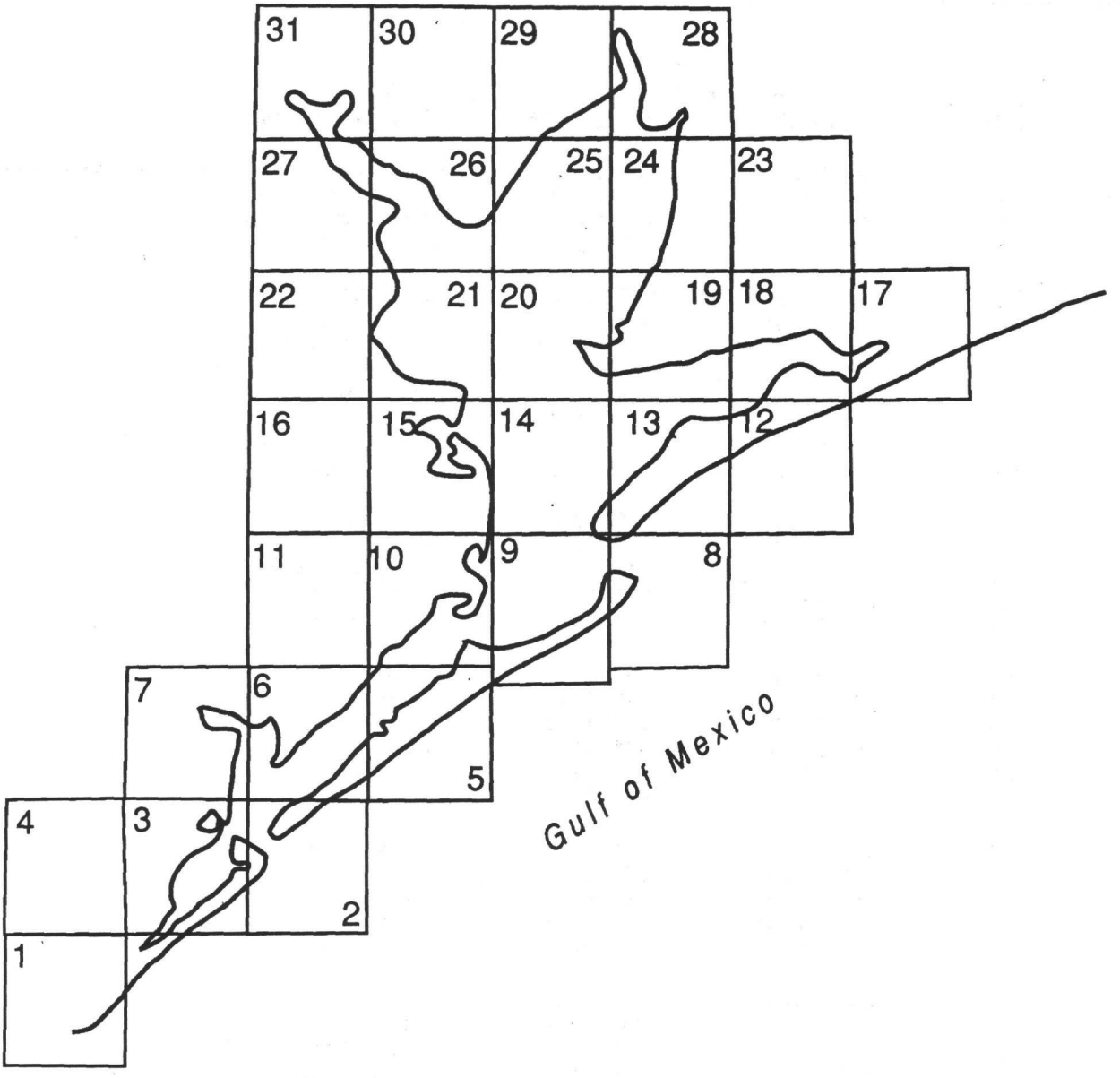


Figure 4. Index map of quadrangles covering the Galveston Bay area (table 7).

Table 7. List of USGS 7.5-minute topographic maps that encompass the Galveston Bay project area. Quadrangle locations shown on figure 4.

Quadrangle Number	Southeast Corner Latitude (N)	Southeast Corner Longitude (W)	USGS Quadrangle Name
1	28° 52.5′	95° 15.0′	Freeport (south of project area)
2	29° 00.0′	95° 00.0′	San Luis Pass
3	29° 00.0′	95° 07.5′	Christmas Point
4	29° 00.0′	95° 15.0′	Oyster Creek
5	29° 07.5′	94° 52.5′	Lake Como
6	29° 07.5′	95° 00.0′	Sea Isle
7	29° 07.5′	95° 07.5′	Hoskins Mound
8	29° 15.0′	94° 37.5′	The Jetties
9	29° 15.0′	94° 45.0′	Galveston
10	29° 15.0′	94° 52.5′	Virginia Point
11	29° 15.0′	95° 00.0′	Hitchcock
12	29° 22.5′	94° 30.0′	Caplen
13	29° 22.5′	94° 37.5′	Flake
14	29° 22.5′	94° 45.0′	Port Bolivar
15	29° 22.5′	94° 52.5′	Texas City
16	29° 22.5′	95° 00.0′	Dickinson
17	29° 30.0′	94° 22.5′	High Island
18	29° 30.0′	94° 30.0′	Frozen Point
19	29° 30.0′	94° 37.5′	Lake Stephenson
20	29° 30.0′	94° 45.0′	Smith Point
21	29° 30.0′	94° 52.5′	Bacliff
22	29° 30.0′	95° 00.0′	League City
23	29° 37.5′	94° 30.0′	Oyster Bayou
24	29° 37.5′	94° 37.5′	Oak Island
25	29° 37.5′	94° 45.0′	Umbrella Point
26	29° 37.5′	94° 52.5′	Morgans Point
27	29° 37.5′	95° 00.0′	La Porte
28	29° 45.0′	94° 37.5′	Anahuac
29	29° 45.0′	94° 45.0′	Cove
30	29° 45.0′	94° 52.5′	Mont Belvieu
31	29° 45.0′	95° 00.0′	Highlands

Table 8. List of common plant species for various marshes based on field surveys. This list characterizes common wetland plants according to general frequencies of occurrence. Many species grow over a range of elevations and salinities and may occur in more than one class.

SALT MARSH	BRACKISH MARSH	FRESH MARSH
LOW	**LOW**	**LOW**
Spartina alterniflora	*Scirpus olneyi*	*Typha spp.*
Juncus roemerianus	*Scirpus californicus*	*Sagittaria spp.*
Scirpus maritimus	*Scirpus maritimus*	*Scirpus californicus*
Scirpus olneyi	*Scirpus americanus*	*Juncus spp.*
Distichlis spicata	*Typha spp.*	*Scirpus americanus*
Batis maritima	*Alternanthera philoxeroides*	*Zizaniopsis miliacea*
Salicornia spp.	*Crinum americanum*	*Alternanthera philoxeroides*
	Eleocharis spp.	*Eichhornia crassipes*
HIGH	*Paspalum vaginatum*	*Eleocharis spp.*
	Bacopa monnieri	*Cyperus articulatus*
Spatina patens	*Zizaniopsis miliacea*	*Ludwigia spp.*
Distichlis spicata	*Panicum dichotomiflorum*	*Pontederia spp.*
Spartina spartinae		
Borrichia frutescens	**HIGH**	**HIGH**
Iva frutescens		
Batis maritima	*Spartina patens*	*Polygonum sp.*
Salicornia virginica	*Distichlis spicata*	*Phragmites australis*
Salicornia bigelovii	*Spartina spartinae*	*Echinochloa crusgalli*
Monanthochloe littoralis	*Spartina cynosuroides*	*Cyperus articulatus*
Limonium nashii	*Borrichia frutescens*	*Cyperus spp.*
Lycium carolinianum	*Paspalum lividum*	*Paspalum lividum*
Aster tenuifolius	*Paspalum vaginatum*	*Scirpus americanus*
Suaeda linearis	*Phragmites australis*	*Leptochloa sp.*
Heliotropium curassavicum	*Panicum virgatum*	*Panicum spp.*
	Echinochloa crusgalli	*Spartina spartinae*
	Leptochloa sp.	
	Scirpus americanus	
	Aster subulatus	
	Aster tenuifolius	
	Hydrocotyle spp.	
	Fimbristylis spp.	
	Setaria geniculata	

Table 9. Species most frequently observed at survey sites in the study area listed in order by number of sites at which plant was reported.

Plant Name	Common Name
Spartina patens	saltmeadow cordgrass
Distichlis spicata	seashore saltgrass
Spartina alterniflora	smooth cordgrass
Batis maritima	saltwort
Salicornia spp.	glasswort
Iva frutescens	big-leaf sumpweed
Spartina spartinae	gulf cordgrass
Borrichia frutescens	sea oxeye
Juncus roemerianus	needlegrass rush
Aster spp.	aster
Typha spp.	cattail
Scirpus maritimus	saltmarsh bulrish
Monanthochloe littoralis	shoregrass

Wetland Indicator Status of Prevalent Plants at Survey Sites

The scientific and common names of plant species identified at field survey sites are presented in table 10. Each species is classified in terms of its wetland indicator status for Region 6, which includes Texas, and for the United States. The indicator status is based on the "National List of Plant Species That Occur in Wetlands: 1988, Texas" (Reed, 1988). In addition, the habit for each species as defined in the list (Reed, 1988) is presented in table 10.

Of the species identified at the survey sites (fig. 3), about 34 percent are classified as obligate (OBL) wetland plants, which means that under natural conditions these plants occur in wetlands with an estimated probability of 99 percent. Among the species are those typically found in wetter conditions, for example, those characterizing topographically low salt, brackish, and fresh marshes (table 8). Such species include *Spartina alterniflora, Juncus roemerianus, Scirpus californicus, Scirpus olneyi, Eleocharis* spp., *Bacopa monnieri, Typha* spp., *Alternanthera philoxeroides,* and *Sagittaria* spp., among others.

Approximately 37 percent of the species listed (table 10) are classified as Facultative Wetland plants (FACW, FACW+, and FACW–). These species usually occur in wetlands or have an estimated probability of 67–99 percent of occurring in wetlands; but occasionally they occur in nonwetland areas. Included, for example, are those species that typically define topographically higher marshes (table 8) such as *Borrichia frutescens, Spartina patens, Spartina spartinae, Phragmites australis, Echinochloa crusgalli, Hydrocotyle bonariensis, Heliotropium curassuvicum,* and *Aster spinosus.* Some Facultative Wetland plants (for instance, *Paspalum vaginatum*) may also occur in wetter, typically low marshes.

About 19 percent of the listed species are classified as Facultative (FAC). These species are equally likely to occur in wetlands or nonwetlands (estimated probability 34–66 percent). Such species include grasses like *Setaria geniculata, Paspalum urvillei,* and *Panicum repens.* Many trees such as *Carya illinoensis, Celtus laevigata, Pinus taeda,* and *Ulmus crassifolia* also are listed as FAC plants.

Only 7 percent of the plants listed are classified as Facultative Upland (FACU). These species are usually not found in wetlands; their estimated probability of occurring in wetlands is 1–33 percent. Such species include the grasses *Cynodon dactylon, Andropogon virginicus,* and *Eragrostis spectabilis.*

Wetland Plant Communities

In the following discussion of coastal wetland communities in the Galveston Bay system, marshes are subdivided into salt, brackish, and fresh communities to assist in the discussions of vegetation composition. A lack of long-term field data precludes the establishment of definite salinity values for these units. Because some plant species can tolerate a relatively large range in salinities (Penfound and Hathaway, 1938; Chabreck, 1972), species tend to overlap between the fresh- and the brackish-marsh communities, and the brackish- and the salt-marsh communities. Overlap between communities also occurs between topographically high and low marshes. Some species can tolerate a range in water regimes, or frequencies of inundation, and therefore may occur in wet, low areas as well as in high, dryer areas.

Mapping of wetlands and aquatic habitats by the USFWS follows the classification by Cowardin and others (1979). As mentioned previously, in general terms emergent vegetation in the

Table 10. Wetland indicator status and common names of plants identified in field surveys. Indicator status from Reed (1988). Abbreviations and symbols given at end of table.

Emergent spp.	Emergent spp.	Status, Reg. 6	Status, Nat.	Habit
Acacia angustissima	Fern acacia	not listed		
Alternanthera philoxeroides	Alligator weed	OBL	OBL	PIEF
Ambrosia psilostachya	Western ragweed	FAC-	FACU-, FAC	PNF
Ambosia trifida	Giant ragweed	FAC	FAC,FACW	ANF
Andropogon glomeratus	Bushy bluestem	FACW+	FACW,OBL	PNG
Andropogon virginicus	Broom-sedge	FACU+	FACU,FAC	PNG
Aristida sp.	Three-awn	FACW-to FACU		
Arundo donax	Giant reed	FAC+	FACU-,FACW	PIG
Aster spinosus	Spiny aster	FACW-	FAC, FACW	PNF
Aster subulatus	Annual saltmarsh aster	OBL	FACW,OBL	ANF
Aster tenuifolius	Perennial saltmarsh aster	OBL	OBL	PNF
Baccharis halimifolia	Eastern B., Sea-myrtle	FACW-	FAC,FACW	NS
Bacopa monnieri	Coastal waterhyssop	OBL	OBL	PNF
Batis maritima	Saltwort	OBL	OBL	N$S
Borrichia frutescens	Sea oxeye	FACW+	FACW+,OBL	NS
Cardiospermum halicacabum	Balloon vine	FAC	FACU,FAC	AIF
Carya aquatica	Water hickory	OBL	OBL	NT
Carya illinoensis	Pecan hickory	FAC+	FACU,FACW	NT
Celtis laevigata	Sugar-berry	FAC	UPL,FACW	NT
Cephalanthus occidentalis	Common buttonbush	OBL	OBL	NT
Crinum americanum	Swamp lily	OBL	OBL	PNF
Cynodon dactylon	Bermuda grass	FACU+	FACU,FAC	PIG
Cyperus articulatus	Jointed flatsedge	OBL	OBL	PNGL
Cyperus elegans	Sticky flatsedge	FACW-	FACW-,FACW	PNGL
Cyperus oxylepis	Sharp-scale flatsedge	FACW	FACW	PNEGL
Cyperus virens	Green flatsedge	FACW	FACW	PNEGL
Dichromena colorata	Starrush whitetop	FACW	FACW	PNGL
Distichlis spicata	Seashore saltgrass	FACW+	FAC+,FACW+	PNG
Desmodium canadense	Tickclover	FAC	FACU, FAC	PNF
Echinochloa crusgalli	Barnyard grass, water millet	FACW-	FACU,FACW	AIG
Eichhornia crassipes	Common water-hyacinth	OBL	OBL	PNE/F (I-Ck.Lst.)
Eleocharis parvula	Dwarf spikesedge	OBL	OBL	PNGL
Eleocharis cellulosa	Gulf Coast spikesedge	OBL	OBL	PNGL
Eleocharis microcarpa	Small-fruit spikerush	OBL	OBL	ANEGL
Eleocharis quadrangulata	Squarestem spikesedge	OBL	OGL	PNEGL
Eleocharis lanceolata ?	Lanceleaf spikesedge	OBL	OBL	PNGL
Eleocharis sp.	Spikesedge	OBL?	OBL?	PIG?
Eragrostis spectabilis	Purple lovegrass	FACU-	UPL,FACU	PNG
Eustachys petraea	Pinewoods finger grass	FAC-	FACU-, FAC	NG
Fimbristylis castanea	Marsh fimbry	OBL	OBL	PNEGL
Forestiera acuminata	Swamp privet	OBL	OBL	NST
Fraxinus caroliniana	Carolina ash	OBL	OBL	NETS
Fraxinus pennsylvanica	Green ash	FACW-	FAC,FACW	NT
Gleditsia aquatica	Water locus	OBL	OBL	NET
Heliotropium curassavicum	Seaside heliotrope	FACW	FACW,OBL	API$F
Hydrocotyle bonariensis	Coastal plain penny-wort	FACW	FACW	PNF
Hymenocallis caroliniana	Carolina spider lily	FACW	FACW	PNF
Ilex vomitoria	Yaupon	FAC-	FAC-,FAC	NST
Ipomea sp.	Morning glory	FAC?	FAC?	?
Iva annua	Annual sumpweed, marsh-elder	FAC	FAC	AIF
Iva angustifolia	Narrowleaf sumpweed	Not listed		
Iva frutescens	Big-leaf sumpweed	FACW	FACW,FACW+	PNH$F
Juncus roemerianus	Needlegrass rush	OBL	OBL	PNGL
Lemna sp.	Duckweed	OBL	OBL	PN/F
Limonium nashii	Sea-lavender	NA*	OBL	PNF
Liquidambar styraciflua	Sweet gum	FAC	FAC,FACW	NT
Lolium perenne	Perennial ryegrass	FACU	FACU-, FAC	PIG
Lycium carolinianum	Carolina wolf-berry	FACW	VACW	NS

Table 10 (Cont.)

Emergent spp.	Common Name	Status, Reg. 6	Status, Nat.	Habit
Machaeranthera phyllocephala	Camphor daisy	FACW	FACU,FACW	ANF
Medicago minima	Small medic	Not listed		
Monanthochloe littoralis	Shoregrass	OBL	OBL	PNEG
Nelumbo lutea	American lotus	OBL	OBL	PNZ/F
Panicum dichotomiflorum	Fall panic grass	FACW	FAC,FACW	ANG
Panicum hians	Gaping panicum	FACW-	FACW-,OBL	PNG
Panicum virgatum	Switchgrass	FACW	FAC,FACW	PNG
Panicum repens	Torpedograss	FAC+	FAC+, FACW-	PIG
Parkinsonia aculeata	Retama	FACW-	FAC-,FACW	NT
Paspalum floridanum	Florida paspalum	FACW-	FACW-,FACW	PNG
Paspalum lividum	Longtom	OBL*	OBL	PNEG
Paspalum monostachyum	Gulfdune paspalum	FACW+	FACW,FACW+	PNG
Paspalum urvillei	Vasey grass	FAC	FAC	PIG
Paspalum vaginatum	Seashore paspalum	FACW+	FACW,OBL	PNG
Phragmites australis	Common reed	FACW	FACW,FACW+	PNEG
Phyla lanceolata	Lance leaf frog fruit	FACW	FACW,OBL	PNF
Physostegia intermedia	Intermediate Lionsheart	OBL	FACW-, OBL	PNF
Pinus taeda	Loblolly pine	FAC-	UPL,FAC	NT
Planera aquatica	Water elm	OBL	OBL	NET
Pluchea purpurascens	Saltmarsh camphor-weed	OBL	FACW+,OBL	AIEF
Pologonum hydropiperoides	Swamp smartweed	OBL	OBL	PNEF
Polygonum ramosissimum	Bushy knotweed	FACW	FACU-,FACW	ANF
Quercus phellos	Willow oak	FACW	FAC+,FACW	NT
Quercus falcata	Southern red oak	FACU	FACU-,FACU	NT
Quercus nigra	Water oak	FAC+	FAC,FACW	NT
Quercus virginiana	Live oak	FACU+	FACU,FACU+	NT
Sabal minor	Dwarf palmetto	FACW	FACW	NST
Sagittaria falcata	Coastal arrow-head	OBL	OBL	PNEF
Salicornia bigelovii	Annual glasswort	OBL*	OBL	ANE$F
Salicornia virginica	Perennial glasswort	OBL*	OBL	PNE$F
Salix nigra	Black willow	FACW+	UPL, OBL	NT
Sapium sebiferum	Chinese tallow	FACU+	FACU+,FAC	IT
Scirpus americanus	Olney's (American) bulrush	OBL	OBL	PNEGL
Scirpus californicus	California bulbush	OBL	OBL	PNEGL
Scirpus maritimus	Saltmarsh bulrush	NI	OBL	PNEGL
Scirpus olneyi (S. americanus)	Olney's bulrush	OBL	OBL	PNEGL
Sesbania drummondii	Drummond's rattle-bush	FACW	FACW	NSH
Sesuvium portulacastrum	Sea-purslane	FACW	FACW	PN$F
Setaria geniculata	Knotroot bristlegrass	FAC	FAC	PNG
Setaria magna	Giant bristlegrass	FACW	FACW,FACW+	ANEG
Sisyrichium exile	Yellow blue-eyed grass	FACW	FAC, FACW-	AIF
Solidago altissima	Tall goldenrod	FACU	FACU-, FACU+	PNF
Solidago sempervirens	Seaside golden-rod	FACW-	FACW-,FACW	PN$F
Spartina spartinae	Gulf cordgrass	FACW+	FACW+,OBL	PNG
Spartina alterniflora	Smooth cordgrass	OBL	OBL	PNEG
Spartina cynosuroides	Big cordgrass	OBL	OBL	PNEG
Spartina patens	Saltmeadow (marshhay) cordgrass	FACW	FACW,OBL	PNG
Spartina pectinata	Prairie cordgrass	FACW+	FACW,OBL	PNG
Spiranthes ovalis	October ladiestresses	FAC*	FAC	PNF
Sporobolus virginicus	Seashore dropseed	FACW+	FACW+	PNG
Sphenoclea zeylanica	Chicken-spike (piefruit)			
Suaeda linearis	Annual seepweed	OBL	OBL	ANEF
Tamarix gallica	Salt cedar	FACW	FAC, FACW	IT
Taxodium distichum	Bald cypress	OBL	OBL	NET
Teucrium cubense	Small coast germander	FAC+	UPL, FACW	APNF
Typha spp.	Cattail	OBL	OBL	PNEF
Ulmus americana	American elm	FAC	FAC,FACW	NT
Ulmus crassifolia	Cedar elm	FAC	FAC	NT
Vigna luteola	Cowpea	FACW-	FACW-,FACW	PNVF
Zizaniopsis miliacea	Marsh millet, giant cutgrass	OBL	OBL	PNG

Table 10 (Cont.)

Habitat symbols	Characteristic or life form
A =	Annual
E =	Emergent
F =	Forb
/ =	Floating
G =	grass
GL =	Grass like
H =	Partly woody
HS =	Half shrub
I =	Introduced
N =	Native
P =	Perennial
S =	Shrub
Z =	Submerged
$ =	Succulent
T =	Tree
V =	Herbaceous vine
WV =	Woody vine
NA =	No agreement by regional panel
* =	Tentative assignment based on limited information
"+"=	More frequently found in wetland
"-"=	Less frequently found in wetland

ABBREVIATION	INDICATOR CATEGORY	DESCRIPTION
OBL	Obligate wetland	Occur almost always (est. prob. >99%) under natural conditions in wetlands.
FACW	Facultative wetland	Usually occur in wetlands (est. prob. 67-99%), but occasionally found in nonwetlands.
FAC	Facultative	Equally likely to occur in wetlands or nonwetlands (est. prob. 34-66%).
FACU	Facultative upland	Usually occur in nonwetlnads (est. prob. 67-99%), but occasionally found in wetlands (e.p. 1-33%).
UPL	Obligate upland	Occur in wetlands in another region, but occur almost always (e.p. >99%) under natural conditions in nonwetlands

Estuarine system corresponds to salt and brackish marshes and emergent vegetation in the Palustrine system corresponds to fresh marshes. Water regimes used as modifiers in classifying and mapping wetlands help define high and low wetlands (table 6).

Salt-Marsh Community

Salt marshes were examined principally on Follets and Galveston Islands, and Bolivar Peninsula, along the inland margin of West Bay, near Texas City, and at Houston and Smith Points (figs. 5 through 9). Prevalent species in the salt-marsh community include *Spartina alterniflora* (smooth cordgrass), *Batis maritima* (saltwort), *Distichlis spicata* (saltgrass), *Salicornia virginica* and *Salicornia bigelovii* (glasswort), *Borrichia frutescens* (sea-oxeye), *Monanthochloe littoralis* (shoregrass), *Juncus roemerianus* (needlegrass rush or blackrush), *Suaeda linearis* (seepweed), *Scirpus maritimus* (salt-marsh bulrush), *Limonium nashii* (sea-lavender), *Aster tenuifolius* (perennial saltmarsh aster), and *Lycium carolinianum* (Carolina wolfberry). At higher elevations, *Spartina patens* (marshhay or saltmeadow cordgrass) and *Spartina spartinae* (Gulf cordgrass) occur, although these species are more common in brackish marshes. *Iva frutescens* (big-leaf sumpweed) is locally abundant at higher elevations such as along natural levees.

The low-salt-marsh community is dominated by *Spartina alterniflora*, which lives in the intertidal zone (fig. 5). Species intermixed most frequently with *Spartina alterniflora* along the upper part of the intertidal zone include *Batis maritima* (fig. 6), *Distichlis spicata* (fig. 7), *Scirpus maritimus*, *Juncus roemerianus*, and *Salicornia virginica.*

Wind-tidal sand flats are common features in some areas, especially on the barrier islands (fig. 10). Although algal mats are abundant in these areas, the flats are generally barren of emergent vegetation because of intermittent salt-water flooding and subsequent evaporation—a process that concentrates salts and inhibits the growth of most plants. Soil salinities on the flats can reach concentrations high enough to kill *Spartina alterniflora* and *Spartina patens* (Webb, 1983). The flats may locally have scattered salt-marsh vegetation. Common plant species are *Salicornia virginica, Salicornia bigelovii, Monanthochloe littoralis*, and *Batis maritima* (fig. 10). Zonation of some salt-marsh species is well defined by elevation transects at Smith Point (fig. 11), in the Brazoria National Wildlife Refuge (fig. 12), and other locations (appendix C).

The salt-marsh community corresponds in general terms to salt marshes (and locally, salt flats) defined by Shaw and Fredine (1956), Fisher and others (1972, 1973), Gosselink and others (1979), and White and others (1985) (table 4), and to saline wetland species identified by Lazarine (n.d.). In accordance with the classification of wetlands by Cowardin and others (1979), this community is designated (down to class) as estuarine, intertidal, emergent wetland (E_2EM). The water regime modifier, "regularly flooded" (N), is used most frequently to identify low salt marshes; the modifier, "irregularly flooded" (P), is used to define higher marshes (table 6). (The classification by Cowardin and others [1979] has provisions for going beyond the class level and designating species dominance type, water chemistry, and human modifications; examples of the classification given here, however, will be only down to class and water regime.)

Brackish-Marsh Community

The brackish-marsh community is transitional between salt marshes and fresh marshes. These areas are affected both by storm-tidal flooding from bay-estuary-lagoon and Gulf waters and by fresh-water inundation from rivers, precipitation and runoff, or ground water. Because the

Figure 5. Low salt-marsh community of *Spartina alterniflora* and open water on the inland margins of Jones Bay (east end of West Bay). Site No. 10-7, Virginia Point Quad. View is toward Galveston Island.

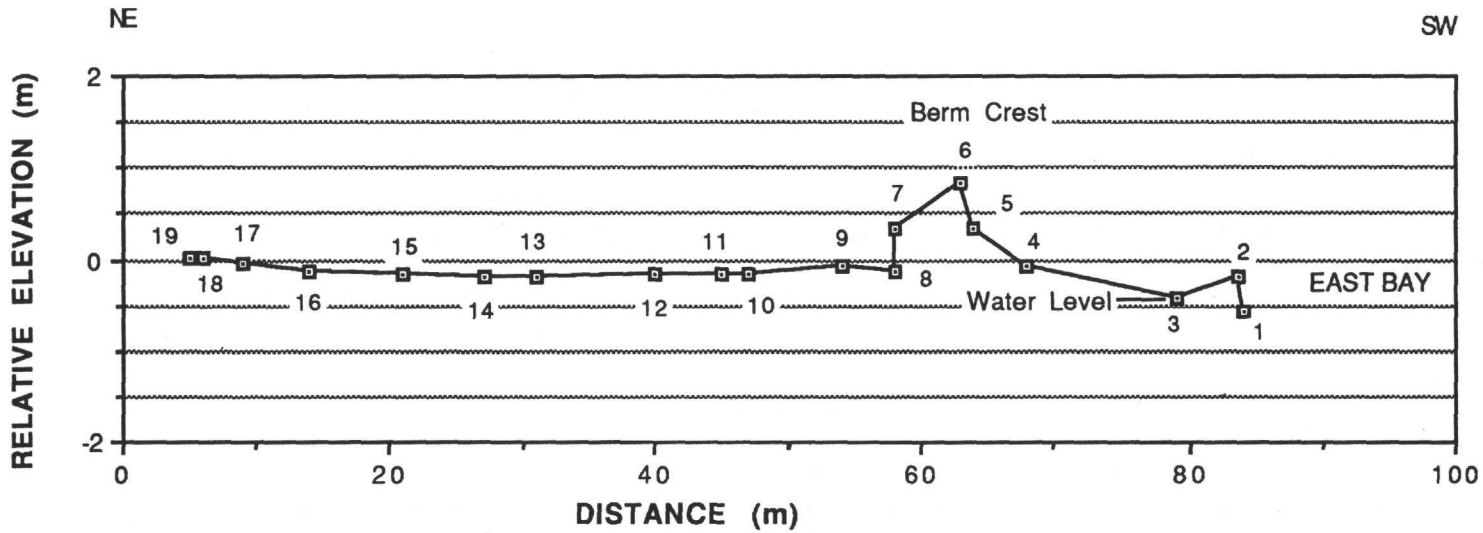
Figure 6. Salt-marsh community on Follets Island. *Batis maritima*, in foreground, intergrades with *Spartina alterniflora*, in background. Site No. 3-3, Christmas Point Quad. View is landward. See survey line at this site in appendix C.

Figure 7. Low salt-marsh community inland from West Bay. *Distichlis spicata* and scattered *Spartina alterniflora* are in the foreground. *Spartina alterniflora* becomes dominant as elevation decreases in distance. *Scirpus maritimus* is abundant on the margins of the tidal pond on the right; the dark assemblage along the margins of ponds in the upper left is *Juncus roemerianus.* Site No. 10-3, Virginia Point Quad. See survey line at this site in appendix C.

Figure 8. Salt-marsh community on the bayward margin of Bolivar Peninsula. *Spartina patens* and *Distichlis spicata* intergrade with *Scirpus maritimus.* In distance *Spartina alterniflora* is dominant in more regularly flooded areas. Site No. 18-1, Frozen Point Quad. View is toward East Bay.

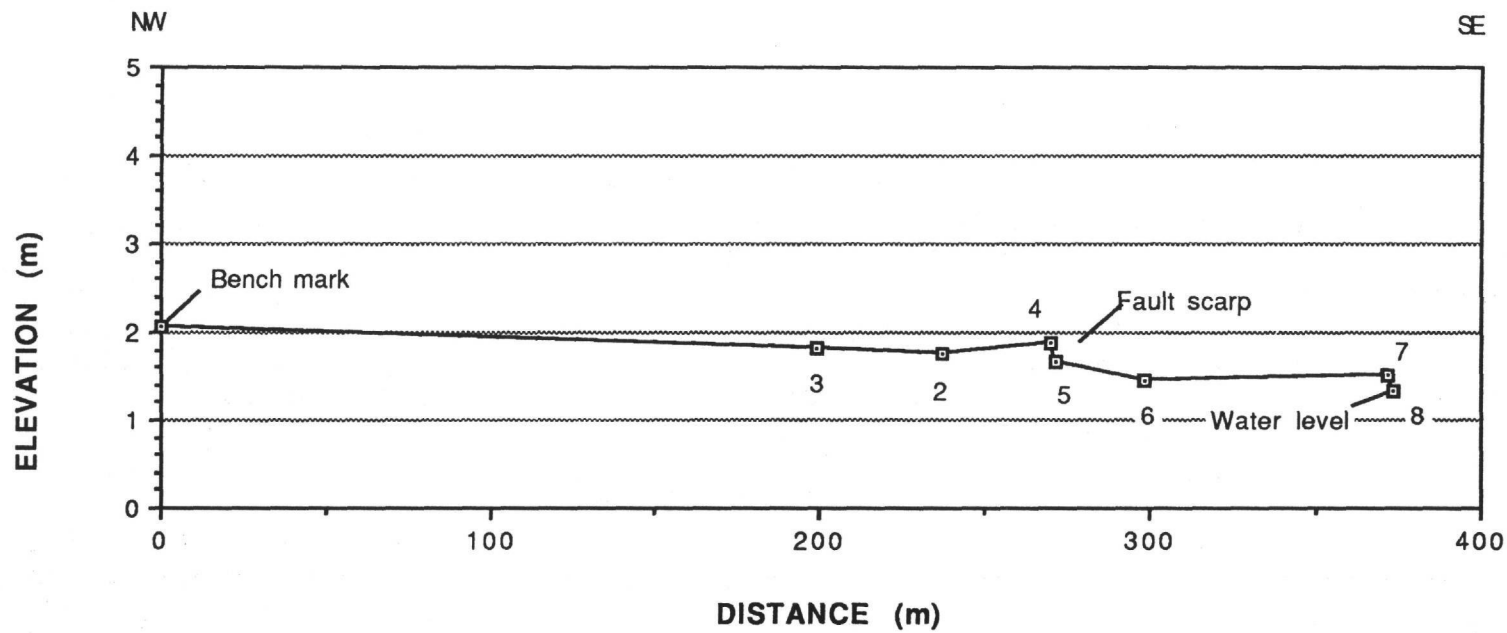
Figure 9. Salt-marsh community at Houston Point. *Spartina alterniflora* dominates the low marsh in this area and intergrades with *Distichlis spicata* along higher margins. Species in the high marsh include *Spartina patens*, *Aster* sp., *Borrichia frutescens*, *Spartina spartinae*, *Iva frutescens*, and *Lycium carolinianum*. Site No. 26-7, Morgans Point Quad. View is inland (NW).

Figure 10. Salt marsh/sand flat community on Follets Island. Species include *Batis maritima*, *Monanthochloe littoralis*, and *Salicornia* spp. Site No. 3-3, Christmas Point Quad. View is southwestward, roughly parallel to island. See survey line for this site in appendix C.



1	Base of erosional scarp	11 to 13	*Distichlis spicata*
2 to 3	*Spartina alterniflora*	13 to 15	*Spartina alterniflora-Distichlis spicata*
3 to 4	Erosional clay ramp	15 to 16	*Scirpus maritimus-S. alterniflora-Distichlis*
4 to 8	Shell berm	16 to 17	*Distichlis-S. alterniflora-Scirpus-Borrichia frutescens*
8 to 9	*Juncus roemerianus*	17 to 18	*Spartina spartinae*
9 to 10	*Spartina patens*	18 to 19	*S. spartinae-Spartina patens-Iva frutescens-Borrichia*
10 to 11	*Spartina alterniflora-Distichlis spicata*		

Figure 11. Profile of salt marsh at Smith Point showing relative elevations of plant communities. Site No. 20-1.



PLANT COMMUNITIES AND GEOMORPHIC FEATURES ALONG PROFILE

BM to 2	*Spartina spartinae (80%), Setaria geniculata, Aster sp., Iva annua, others (20%)*
2 to 4	*Spartina spartinae (90%)*
4 to 5	Fault Scarp
5 to 6	Mixed flat and emergent vegetation *Monanthochloe-Salicornia-Batis*
6 to 7	*Distichlis spicata (90%), Salicornia sp. (10%)*

Figure 12. Profile of brackish marsh in the Brazoria National Wildlife Refuge showing relative elevations of plant communities. Site No. 3-1.

brackish-marsh community encompasses a range in salinities from near fresh to near saline, the vegetation types cover a broad spectrum. Species range from those typical of saline marshes to those that occur in fresh marshes.

Areas in which brackish-marsh surveys were conducted included the Brazoria National Wildlife Refuge (figs. 13 and 14), Anahuac National Wildlife Refuge and near High Island (figs. 15 and 16), Galveston and Follets Islands (figs. 17 and 18), and Trinity River delta (figs. 19 and 20). Among the dominant species in topographically higher areas of this community are *Spartina patens, Spartina spartinae, Borrichia frutescens, Phragmites australis* (common reed), *Solidago sempervirens* (seaside goldenrod), *Panicum virgatum* (switchgrass) and *Spartina cynosuroides* (big cordgrass). Other prevalent species, most of which occur in lower, wetter areas (relative to the cordgrasses) include *Scirpus maritimus, Scirpus olneyi* (Olney bulrush) (fig. 15), *Juncus roemerianus, Typha* spp. (cattail), *Paspalum vaginatum* (seashore paspalum), *Scirpus californicus* (California bulrush), *Scirpus americanus* (three-square bulrush), *Alternanthera philoxeroides* (alligatorweed), *Eleocharis* spp. (spikesedges), *Bacopa monnieri* (coastal waterhyssop), *Echinochloa crusgalli* (barnyard grass or water millet), and *Aster tenuifolius* and *Aster subulatus* (saline and saltmarsh aster), among others. *Spartina alterniflora* also occurs locally in the brackish-marsh community (fig. 13). Zonation of various species with respect to elevation are illustrated by marsh profiles on the Trinity River delta, and in the Brazoria (Hoskins Mound profiles), and Anahuac National Wildlife Refuges (appendix C). There are considerable differences in brackish marsh composition in the Brazoria and Anahuac National Wildlife Refuges (figs. 13 and 15) compared to brackish marshes in the Trinity River delta (figs. 19 and 20). In general, the Trinity River delta, which has extensive areas of *Alternanthera philoxeroides* (fig. 19) and other species occurring in fresher areas (fig. 20), is toward the fresh end of the brackish salinity spectrum.

The brackish-marsh community corresponds, generally, with the coastal salt meadows (grading into fresh marshes) defined by Shaw and Fredine (1956), the brackish (closed) and brackish- to fresh-water marsh by Fisher and others (1972, 1973), the brackish and intermediate marsh by Gosselink and others (1979), and the brackish marsh by Harcombe and Neaville (1977) (table 2) and White and others (1985) (table 4). In the classification system of Cowardin and others (1979), this community is generally designated (down to class) as estuarine, intertidal, emergent wetland (E_2EM). Water regimes are generally the same as for the salt marshes—regularly flooded (N) (low marshes) and irregularly flooded (P) (high marshes).

Spartina spartinae is a common species in brackish marshes (fig. 14). Because of its tendency to occur mostly in topographically higher areas, it has been placed in the marsh, transitional (occurring between wetlands and uplands), and prairie communities by various researchers. It occurs in many areas in conjunction with *Spartina patens*, becoming more predominant and extensive (relative to *Spartina patens*) south of the Galveston Bay area along the Texas coast. Tharp (1926) listed *Spartina spartinae* as a dominant species in the coastal marsh community, but also included it as part of a coastal prairie-marsh-transition community. McAtee (1976) noted that *Spartina spartinae* flourishes at an elevation between lowland marshes and higher uplands, and apparently requires periodic inundation. The U.S. Army Corps of Engineers, which has jurisdictional responsibilities for wetlands, considers it to be a transitional species (Lazarine, n.d.). Many classifications place it in wetlands, transitional areas, and prairie grasslands (Fisher and others, 1972, 1973; Correll and Correll, 1975; White and others, 1985), presumably depending on associated plants and soil-moisture conditions reflecting inundation frequency. In the list of wetland plants of Texas (Reed, 1988), *Spartina spartinae* is categorized as usually found in wetlands, but occasionally found in nonwetlands. Harcombe and Neaville (1977) place it in their cordgrass prairie unit (table 2), but also list it in a checklist of marsh species and note that it probably once was more extensive (in Chambers County) as an intermediate type between upland prairie and brackish marsh. Fleetwood (n.d.) reported that *Spartina spartinae* was the predominant species in his salty prairie community.

Figure 13. Brackish-marsh community in the Brazoria National Wildlife Refuge southwest of Hoskins Mound. Although dominant species are *Spartina patens* and *Distichlis spicata*, *Spartina alterniflora* occurs along the tidal channel. *Ruppia maritima* (widgeongrass) occurs in the channel. Site No. 3-2, Christmas Point and Oyster Creek Quads. View is landward. This site is on the Oyster Creek Quad. at the west end of the survey line at this site. See survey line in appendix C.

Figure 14. Brackish-marsh community in the Brazoria National Wildlife Refuge east of Hoskins Mound. *Spartina spartinae* is dominant in the foreground and *Juncus roemerianus* in the background. Site No. 7-1, Hoskins Mound Quad. Several elevation surveys were conducted in this area (appendix C).

Figure 15. High and low brackish-marsh communities in the Anahuac National Wildlife Refuge. The high-marsh community is dominated by *Spartina patens* and *Distichlis spicata* in foreground, and the low marsh by *Scirpus olneyi* in the center of the photograph. Site No. 18-9, Frozen Point Quad.; view is landward (NW). See survey line in appendix C.

Figure 16. Brackish-marsh community dominated by *Spartina patens*, west of High Island. Site No. 17-1, High Island Quad.; view is landward (NW).

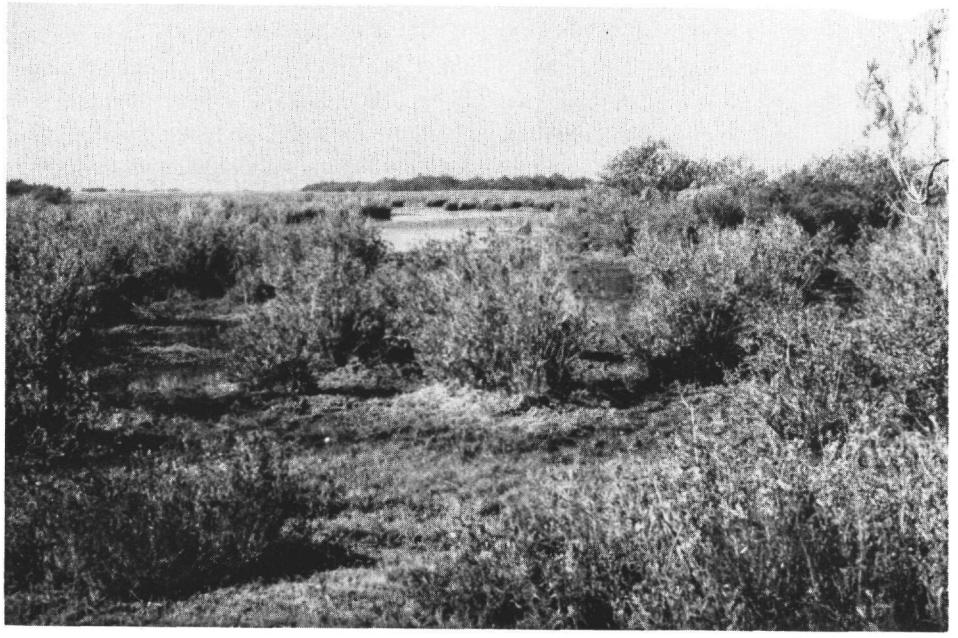


Figure 17. Brackish-marsh community in a swale on Galveston Island. A dike in this area separates a fresher from a more saline assemblage. Species in the fresher area include *Bacopa monnieri*, *Spartina patens*, *Borrichia frutescens*, and probably *Paspalum vaginatum* and *Scirpus californicus*. The more saline community (not shown in the photograph) includes *Distichlis spicata*, *Batis maritima*, and *Salicornia* spp. Site No. 10-16, Virginia Point Quad.; view is southwest.

Figure 18. Brackish- to fresh-marsh community in a depression on Follets Island, gulfward of highway. Species include *Typha* sp., *Paspalum vaginatum*, *Scirpus americanus*, and *Phragmites australis*. Bayward, across the highway, a salt-marsh community occurs. Site No. 3-12, Christmas Point Quad.; view is gulfward.

Figure 19. Brackish-marsh community on the Trinity River delta. This area is dominated by *Alternanthera philoxeroides* with local patches of *Crinum americanum* (swamp lily). *Phragmites australis* and scattered trees and shrubs line the natural levee along the Trinity River to the left of the photograph. Site No. 28-11, Anahuac Quad.; view is down river toward Trinity Bay.

Figure 20. Brackish-marsh community on the Trinity River delta near the delta/bay margin. Species include *Scirpus olneyi, Panicum dichotomiflorum, Echinochloa crusgalli, Bacopa monnieri,* and *Eleocharis parvula*. This dynamic area of the delta has a dramatic seasonal change in vegetation as described by White and Calnan (1990). Site No. 28-1, Anahuac Quad.; view is westward.

Brackish marshes dominate the coastal marsh community between High Island and Trinity Bay (fig. 2). They are also widely distributed along the lower reaches of the Trinity bay-head delta below Interstate Highway 10, inland from parts of West Bay, and inland of the Intracoastal Waterway in the Christmas Bay area. They occur in swales and intergrade with salt marshes and sand flats on Galveston Island (fig. 17) and Bolivar Peninsula.

Fresh-Marsh Community

Surveys of fresh to intermediate marshes were conducted along the Trinity (figs. 21 and 22) and San Jacinto Rivers (fig. 23), and at other inland sites (figs. 24 and 25). Environments in which fresh marshes occur are generally beyond the limits of salt-water flooding except perhaps locally during hurricanes. The fresh-water influence from rivers, precipitation, runoff, and ground water is sufficient to maintain a fresher water vegetation community (although many species also occur in brackish marshes) consisting of species such as *Typha* spp., *Phragmites australis, Zizaniopsis miliacea* (marsh millet or giant cutgrass), *Sagittaria falcata* (coastal arrowhead), *Scirpus californicus, Eleocharis quadrangulata* (squarestem spikesedge) and other species of *Eleocharis, Cyperus* spp. (flatsedges), *Bacopa monnieri, Alternanthera philoxeroides, Paspalum lividum* (longtom), and *Eichhornia crassipes* (water hyacinth) in lower, wetter areas. Topographically higher areas generally include such species as *Phragmites australis, Paspalum* spp., *Polygonum* spp. (smartweeds), *Panicum* spp. (panic grasses), *Rhynchospora* spp. (beakrushes), and *Aster spinosus* (spiney aster). Shrubs such as *Sesbania drummondii* (rattlebush) are scattered around the margins of some fresh marshes and are locally abundant. Some species that are more common in brackish marshes such as *Spartina spartinae* may also occur in fresh marshes. Harcombe and Neaville (1977) used *Spartina patens* as an indicator of brackish conditions in differentiating brackish from fresh marshes.

The fresh-marsh community corresponds to the deep fresh and shallow fresh marshes of Shaw and Fredine (1956), inland fresh-water marsh and, locally, brackish- to fresh-water marsh of Fisher and others (1972, 1973), and fresh marsh of Fleetwood (n.d.), Harcombe and Neaville (1977) (table 2), Gosselink and others (1979), and White and others (1985) (table 4). Following the classification by Cowardin and others (1979) this community would be designated (down to class) as palustrine, emergent wetland (PEM) in areas where persistent emergent vegetation such as *Typha* spp. is present, and palustrine, aquatic bed (PAB) where floating vascular plants such as *Eichhornia crassipes* occur. A variety of water regimes can be applied under the Cowardin system (table 6). Low fresh marshes are usually characterized by the "semipermanently flooded" (F) or "seasonally flooded" (C) water regimes, and higher marshes by the "temporarily flooded" (A) regime, and occasionally the seasonally flooded regime. Fresh-water marshes in tidally influenced areas, have a different set of modifiers ranging from "semipermanently flooded—tidal" (T) to "temporarily flooded—tidal" (S) (table 6). These regimes are applicable along river systems, for example, and have been applied to some fresh marshes in the Trinity River delta.

Fresh marshes occur inland along river or fluvial systems and in upland basins and depressions on the mainland and perhaps locally on the barrier islands (fig. 18). Upstream along the river valleys of the Trinity and San Jacinto Rivers, salinities decrease and fresh marshes intergrade with and replace brackish marshes (figs. 21 through 23). Fresh marshes also occur locally in swales on the modern barrier islands and on the Pleistocene barrier strandplain, and in abandoned channels and courses of the Pleistocene fluvial-deltaic systems (fig. 2).

Figure 21. Fresh-marsh community in the Trinity River valley north of Interstate Highway 10. Species include *Cyperus articulatus* (jointed flatsedge), *Sagittaria falcata, Scirpus californicus, Zizaniopsis miliacea,* and *Alternanthera philoxeroides.* Site No. 29-3, Cove Quad.; view is westward.

Figure 22. Fresh- to brackish-marsh community on the Trinity River delta near Old River Lake. Species include *Zizaniopsis miliacea, Sagittaria falcata,* and *Alternanthera philoxeroides.* Site No. 29-2, Cove Quad.; view is northwest.

Figure 23. Fresh-marsh and forested-wetland communities in the San Jacinto River valley. Marsh species include *Typha* sp., *Scirpus californicus*, and *Eleocharis* sp. Site No. 31-5, Highlands Quad.; view is southeastward.

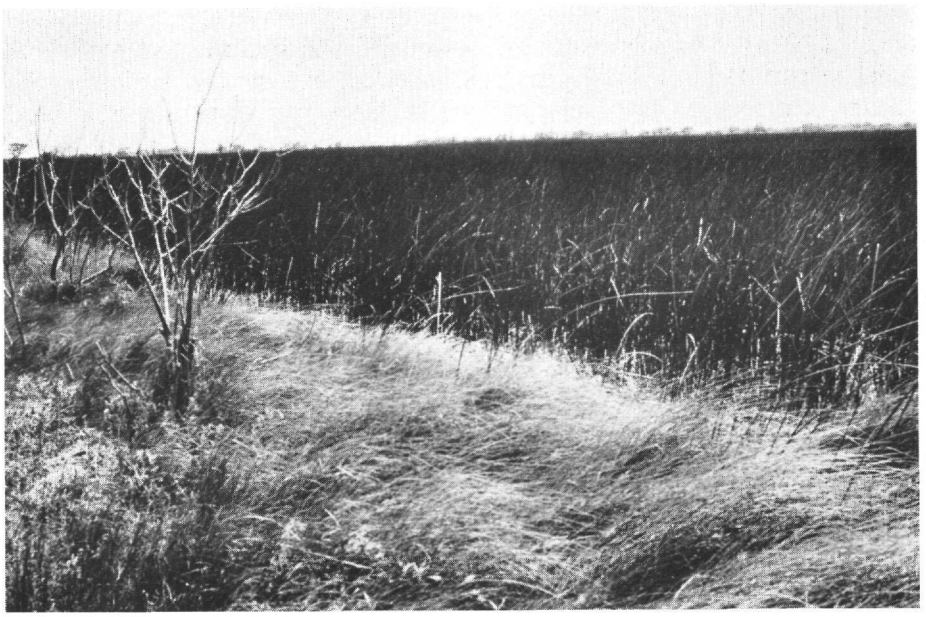


Figure 24. Fresh-marsh community of *Scirpus californicus* in an ox-bow lake in the Brazoria National Wildlife Refuge. Site No. 4-5, Oyster Creek Quad.; view is westward.

Figure 25. Fresh-marsh community dominated by *Eleocharis quadrangulata* (squarestem spikesedge). *Hymenocallis caroliniana* (Carolina spider lily) is the flowering plant. Site No. 15-6, Texas City Quad.

Forested Wetland Communities (Swamps)

Forested wetlands as defined by Cowardin and others (1979) include swamps as well as forested areas less frequently inundated. Swamps, as defined most commonly, are woodlands or forested areas that contain saturated soils or are inundated by water during much of the year. This community is located almost entirely in the alluvial valley of the Trinity River. The swamp community is composed principally of *Taxodium distichum* (bald cypress) (fig. 26). Associated species may include *Cephalanthus occidentalis* (button bush), *Planera aquatica* (water-elm), and *Carya aquatic* (water hickory) (Harcombe and Neaville, 1977).

Areas along the floodplains of streams (excluding swamps) support assemblages of water-tolerant trees and shrubs (fig. 23) that are inundated less frequently than swamps. Trees and shrubs occurring in these areas include *Planera aquatica, Quercus phellos* (willow oak), *Quercus nigra* (water oak), *Fraxinus pennsylvanica* (Green ash), *Fraxinus caroliniana* (Carolina ash), *Salix nigra* (black willow), *Ulmus* spp. (elm), *Celtis laevigata* (sugar-berry), *Carya illinoensis* (pecan hickory), *Carya aquatica* (water hickory), *Cephalanthus occidentalis, Ilex vomitoria* (yaupon), *Liquidambar styraciflua* (sweet gum), *Sepium sebiferum* (Chinese tallow), *Parkinsonia aculata* (retama), *Gleditsia aquatica* (water locus), and *Sabal minor* (dwarf palmetto). Occurring with hardwoods in some topographically higher areas is *Pinus taeda* (loblolly pine).

Submerged Vegetation Community

Submerged vegetation has a limited distribution in the Galveston Bay system. It occurs principally in patches along the margins of the Trinity River delta, upper Trinity Bay, and Christmas Bay (figs. 27 and 28). Plant species occurring in the comparatively fresh area of the Trinity River delta include *Ruppia maritima* (widgeongrass), *Vallisneria americana* (wild celery), *Potamogeton pusillus* (pondweed), and *Najas quadalupensis* (water nymph) (Pulich and others, 1991). The dominant submerged vegetation along the north and eastern shores of upper Trinity Bay is *Ruppia maritima* (Pulich and White, 1991). In the Christmas Bay area, near Follets island, several true seagrasses occur including *Halodule wrightii* (shoalgrass), the dominant species, *Halophila engelmannii* (clovergrass), and *Thalassia testudinum* (turtlegrass) (Pulich and White, 1991). *Ruppia maritima* is abundant in many inland water bodies and tidal creeks (fig. 13).

The submerged-vegetation community is classified under sounds and bays by Shaw and Fredine (1956); as grassflats by Fisher and others (1972, 1973), and White and others (1985); and as submerged vegetation by Diener (1975). Submerged-vegetation communities are designated as Estuarine, subtidal, aquatic bed (E_1AB) in the classification by Cowardin and others (1979); the water-regime modifier is "subtidal" (L) (table 6).

Soils and Wetland Community Relationships

At the more than 135 sites surveyed around the Galveston Bay system, approximately 40 soil types were identified from county soil surveys (table 11). Several soils were encountered more frequently than others, and can be considered the dominant soils corresponding to wetland communities. For example, the soil most frequently occurring at wetland survey sites was the Harris clay. This typically saline, poorly drained soil is flooded by abnormally high tides, and

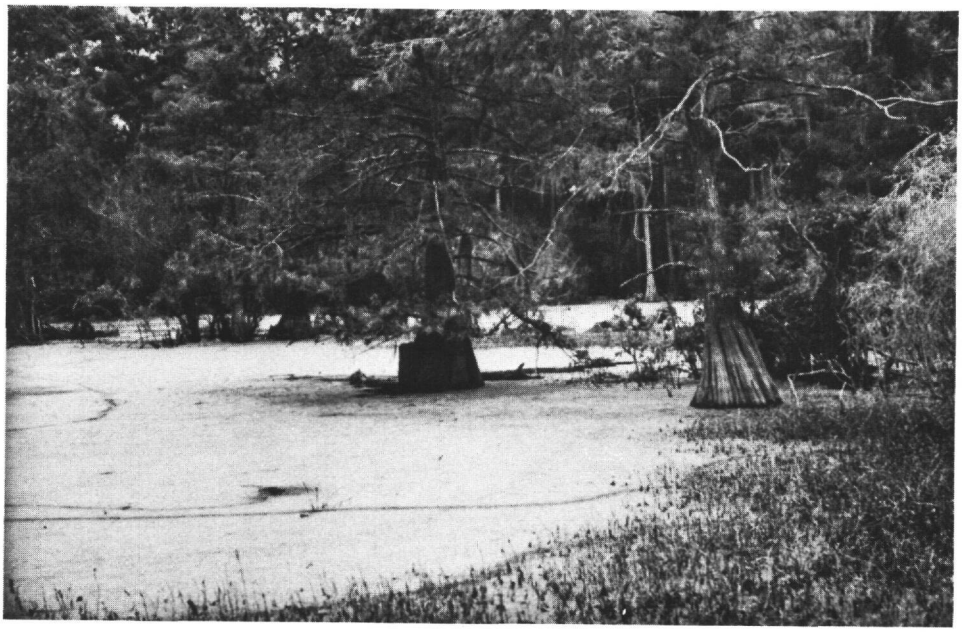


Figure 26. Swamp community dominated by *Taxodium distichum* along the Trinity River inland from Interstate Highway 10. Site No. 29-3, Cove Quad.; view is northward.

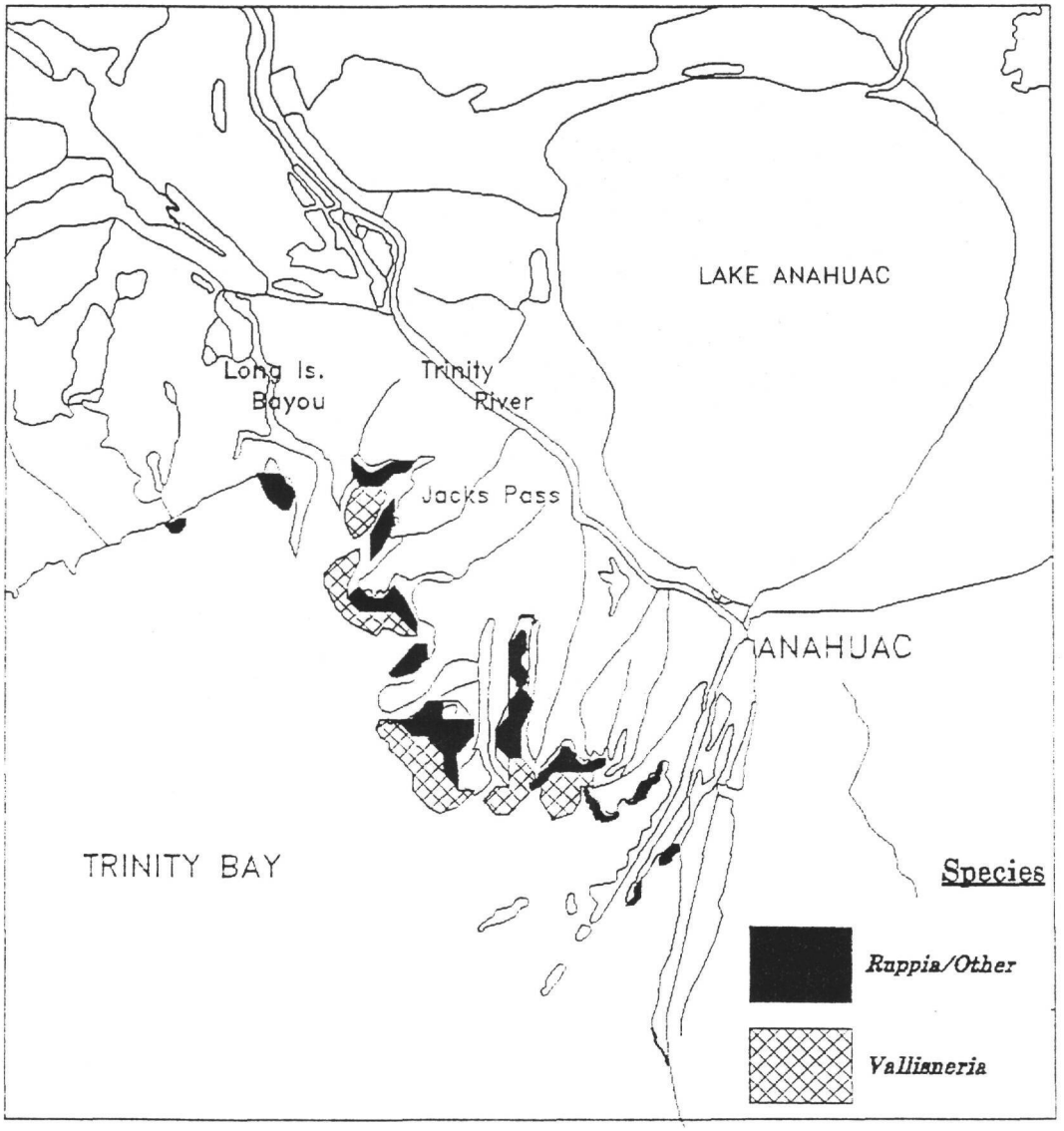


Figure 27. Generalized map showing the locations of submerged vegetation along the margins of the Trinity River delta. (From Pulich and others, 1991)

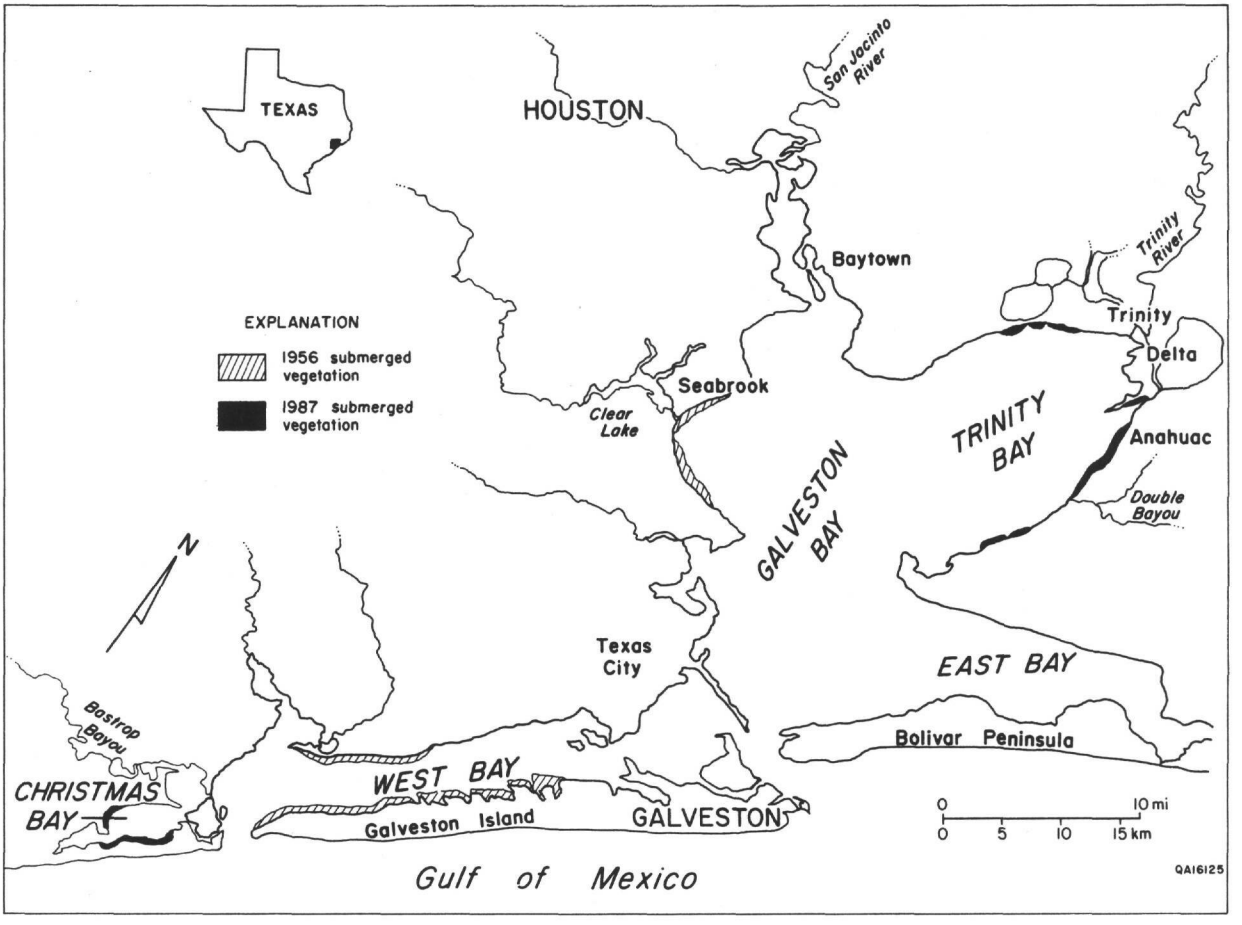


Figure 28. Generalized map showing the locations of submerged vegetation in 1956 and 1987 in the Galveston Bay system excluding areas along the Trinity Delta. The 1956 distribution of submerged vegetation in Trinity and Christmas Bays is not shown. (Modified from Pulich and White, 1991)

Table 11. Characteristics of soils at survey sites. (From USDA Soil Conservation Service County Soil Surveys—Crout, 1976; Wheeler and others, 1976; Crenwelge and others, 1981; and Crenwelge and others, 1988).

SOIL	SALINE OR NONSALINE	DRAINAGE	FREQUENCY OF FLOODING	WATER TABLE
Aldine-urban cmplex				
Asa silty clay loam	nonsaline	well drained	rarely flooded	
Atasco fine sandy loam, 1 to 4% slopes	nonsaline	moderately well drained		lower soil saturated 2-4 months in wet season
Bacliff clay	nonsaline	poorly drained	rarely flooded	<1ft below surface during winter
Bernard clay loam	nonsaline	somewhat poorly drained	rarely flooded	<2 ft below surface during winter
Boy loamy fine sand	nonsaline	somewhat poorly drained		saturated in and above lower soil in wet season
Brazoria clay, 0-1% slopes	nonsaline	somewhat poorly drained	rarely flooded	1 to 3 ft below surface in winter
Caplen mucky silty clay loam	saline	very poorly drained	flooded daily by 2-12 inches of tide water	soil saturated
Caplen-Tracosa complex	saline	very poorly drained	flooded daily by 2-12 inches of tide water	saturated throughout year
Clemville silty clay loam	nonsaline	well drained	rarely flooded	
Follet clay Loam	saline	very poorly drained	flooded daily during high tide	at or near surface most of year
Galveston-Nass complex	nonsaline-slightly saline	excessively to very poorly drained	occasionally to frequently flooded	36-60 inches below to 24 inches above surface
Galveston-Nass complex				
Harris-Tracosa complex	saline	very poorly drained	occasionally to frequently flooded	<20 inches below surface throughout year
Harris clay	typically saline	poorly drained	flooded during abnormally high tides	<20 inches below surface
Ijam clay, 0-2% slopes	saline	poorly drained	rarely flooded	<1.5 ft below surface during winter
Ijam clay, 2-8% slopes	saline	poorly drained	rarely flooded	<1.5 ft below surface during winter
Ijam soils	moderately saline	very poorly drained		at surface to 30 inches below surface
Kaman clay	nonsaline	poorly drained	occasionally flooded	saturated within 30 inches of surface most of year
Karankawa mucky Loam	saline	very poorly drained	flooded daily with 2 to 12 inches of tide water	depressions 0.3 ft deep, soil saturated
Kaufman clay	nonsaline	somewhat poorly drained	frequently flooded	surface to 50 inches below during wet season
Kemah-urban land complex	nonsaline	somewhat poorly drained	rarely flooded	<1.5 ft below surface during winter
Lake Charles clay, 1-3% slopes		somewhat poorly drained		
Mocarey-leton complex	nonsaline	somewhat poorly to poorly drained	rarely flooded	<3 ft below surface to 1 ft above
Morey silt loam	nonsaline to slightly saline			
Mustang fine sand	nonsaline	poorly drained	frequent flooding	6 to 40 inches below surface
Mustang fine sand, saline	slightly to strongly saline	poorly drained	frequent flooding by abnormally high tides	6 to 20 inches below surface
Mustang-Nass complex	nonsaline to moderately saline	poorly to very poorly drained	occasionally to frequently flooded	<6 inches below to 6 to 24 inches above surface
Mustang-Nass complex				
Narta fine sandy loam	saline	somewhat poorly drained	occasionally flooded	
Narta fine sandy loam	moderately saline	somewhat poorly drained	rarely flooded	<1 ft below surface most of winter
Nass very fine sand loam	slightly to strongly saline	very poorly drained	occasionally flooded by storm tides and rains	near surface or up to 2 ft standing water
Nass-Galveston complex, shell substratum	nonsaline to moderately saline	poorly to somewhat excessively drained	ocassionally to frequently flooded	< 50 inches below (ridges) to 6 to 24 inches above (swales) surface
Placedo clay	saline	very poorly drained	frequently flooded	at or near surface most of year
Sievers loam, 0 to 3% slopes	moderately saline	somewhat poorly drained	rarely flooded	2.5 to 4 ft below surface most of winter
Sumpf clay	nonsaline	poorly drained	ponded for several months during year	
Surfside clay	saline	poorly drained	rarely flooded	2 ft below surface during winter
Tatlum clay Loam	saline	very poorly drained	flooded daily during high tide	saturated to surface throughout year
Tracosa mucky clay	saline	poorly drained to ponded	flooded daily by 2 to 12 inches of tide water	depressions 0.3 ft deep, some permanent water bodies
Tracosa mucky clay-clay, low complex	saline	very poorly drained to ponded	frequently flooded	flooded daily by 2 to 12 inches tidal water
Vamont clay	nonsaline	somewhat poorly drained	rarely flooded	<1.5 ft below surface most of winter
Vamont clay, 1 to 4% slopes	nonsaline	somewhat poorly drained		
Velasco clay	saline	poorly drained		<20 inches below surface most of year
Verland silty clay loam	nonsaline	somewhat poorly drained	rarely flooded	<1.5 ft below surface most of winter
Veston loam	saline	poorly drained	frequently flooded	<2 ft below surface during winter
Veston loam (Galveston Co.)	slightly to strongly saline	poorly drained	frequently flooded	at surface to <2 ft most of year
Veston silty clay loam	strongly saline	poorly drained	flooded by unusually high tide	<10 inches below surface

Table 11 (cont.)

SOIL	DOMINANT PLANTS
Aldine-urban complex	native pine and hardwoods; grasses include little bluestem, beaked panicum, longleaf uniola, brownseed paspalum
Asa silty clay loam	hardwood trees; understory--longleaf uniola (10%), lurid sedge (15%), Virginia wildrye (10%), switchcane (5%), low panicum (5%), nimblewill muhly (5%); forbs such as elephantfoot and drummond waxmallow; vines and shrubs--greenbriar, poison-ivy, yaupon, possumhaw
Atasco fine sandy loam, 1 to 4% slopes	pine (dominant), hardwoods, sedges, beaked panicum, little bluestem
Bacliff clay	little bluestem (dominant), indiangrass, switchgrass, eastern gamagrass, Florida paspalum, big bluestem, brownseed paspalum, panicum, sedges
Bernard clay loam	little bluestem (dominant), indiangrass, switchgrass, eastern gamagrass, Florida paspalum, big bluestem, brownseed paspalum, panicum, sedges
Boy loamy fine sand	pine woodlands; bermudagrass, coastal bermuda grass, and bahiagrass
Brazoria clay, 0 to 1% slopes	hardwood trees; understory--lurid sedge (35%), Virginia wildrye (10%), nimblewill muhly (10%), longleaf uniola (5%), rustyseed paspalum (5%); vines and shrubs--greenbrier, Alabama supplejack, yaupon, American elder, dwarf palmetto
Caplen mucky silty clay loam	marshhay cordgrass, common reed, seashore saltgrass, sagittaria, bulrushes, big cordgrass, smooth cordgrass
Caplen-Tracosa complex	Tracosa--Smooth cordgrass (dominant), seashore saltgrass, glasswort, maritime saltwort, saltmarsh bulrush, widgeongrass; (for Caplen see above)
Clemville silty clay loam	hardwood trees; understory--lurid sedge (15%), Virginia wildrye (10%), longleaf uniola (10%), switchcane (5%), low panicum (5%), nimblewill muhly; forbs (10%) such as elephantfoot and drummond waxmallow; vines and shrubs--greenbrier, poison-ivy, yaupon, possumhaw
Follet clay Loam	smooth cordgrass (90%)
Galveston-Nass complex	swales--marshhay cordgrass, seashore saltgrass, seashore paspalum, gulfdune paspalum, shoregrass, gulf cordgrass, red lovegrass, needlegrass rush, sea-oxeye, glasswort ridges--gulfdune paspalum, marshhay cordgrass,bushy bluestem, red lovegrass, knotroot bristlegrass, bushy bluestem, bermudagrass, baccharis, southern wax myrtle
Harris-Tracosa complex	marshhay cordgrass (50%), seashore saltgrass (10%), seashore paspalum (10%), olney bulrush (10%); 5% forbs--saltmarsh aster, sea-oxeye, bacopa
Harris clay	marshhay cordgrass (50%), seashore saltgrass (25%)
Ijam clay, 0-2% slopes	gulf cordgrass (dominant), little bluestem, switchgrass, indiangrass, marshhay cordgrass, knotroot bristlegrass, longspike tridens
Ijam clay, 2-8% slopes	gulf cordgrass (dominant), little bluestem, switchgrass, indiangrass, marshhay cordgrass, knotroot bristlegrass, longspike tridens
Ijam soils	gulf cordgrass (73%), marshhay cordgrass (2%), common reedgrass (5%), switchgrass (5%), little bluestem (2%), knotroot bristlegrass (2%), forbs (5%)
Kaman clay	common bermudagrass and dallisgrass; woodlands--elm, water oak, beech, willow oak, cypress, palmetto, sedges, longleaf uniola, and switch cane
Karankawa mucky Loam	smooth cordgrass
Kaufman clay	bermudagrasses, dallissgrass, tall fescue, johnsongrass, bluestems, clovers; water-tolerant hardwoods--cypress, water oak, sweetgum
Kemah-urban land complex	*not described*
Lake Charles clay	little bluestem (50%), indiangrass (10%), eastern gamagrass (5%), switchgrass (5%), big bluestem (5%), brownseed paspalum (5%), Florida paspalum (3%)
Mocarey-leton complex	switchgrass, maidencane, eastern gamagrass (dominants); indiangrass, Florida paspalum, longtom, squarestem spikesedge, brownseed paspalum, knotroot bristlegrass, and low panicums; needlerush grass, rushes, sedges carpetgrass, baccharis, sesbania
Morey silt loam	prairie grasses such as bermudagrass, bahiagrass, dallisgrass, bluestems, indiangrass, beaked panicum, paspalums, sedges, and others; woodland species may include loblolly pine, slash pine, white oak, red oak, and sweetgum
Mustang fine sand	gulfdune paspalum (30%), marshhay cordgrass (20%), herbaceous mimosa, beach ground cherry, waxmyrtle, eastern baccharis
Mustang fine sand, saline	*marshhay cordgrass (25%), sedges and rushes (25%), more saline areas--maritime saltwort, shoregrass, glasswort, sea-oxeye, seashore saltgrass*
Mustang-Nass complex	swales--marshhay cordgrass, seashore saltgrass, seashore paspalum, gulfdune paspalum, shoregrass, gulf cordgrass, red lovegrass, needlegrass rush, sea-oxeye, glasswort ridges--gulfdune paspalum, marshhay cordgrass, bushy bluestem, red lovegrass, knotroot bristlegrass, bushy bluestem, bermudagrass, baccharis, southern wax myrtle
Narta fine sandy loam	gulf cordgrass (60%), marshhay cordgrass (5%), switchgrass (5%), little bluestem (5 %), seashore saltgrass (5%), forbs--sea-oxeye gulf cordgrass (dominant), little bluestem, switchgrass, indiangrass, marshhay cordgrass, knotroot bristlegrass, longspike tridens
Nass very fine sand loam	marshhay cordgrass, seashore saltgrass, seashore paspalum
Nass-Galveston complex, shell substratum	swales--marshhay cordgrass, seashore saltgrass, seashore paspalum, gulfdune paspalum, shoregrass, gulf cordgrass, red lovegrass, needlegrass rush, sea-oxeye, glasswort ridges--gulfdune paspalum, marshhay cordgrass, bushy bluestem, red lovegrass, knotroot bristlegrass, bushy bluestem, bermudagrass, baccharis, southern wax myrtle
Placedo clay	marshhay cordgrass and seashore saltgrass (dominant), seashore paspalum, seashore dropseed, olney bulrush, saltmarsh bulrush, saltmarsh aster, needlerush grass; less saline areas--common reed, seashore paspalum, longtom
Sievers loam, 0 to 3% slopes	gulf cordgrass (dominant), little bluestem, switchgrass, indiangrass, marshhay cordgrass, knotroot bristlegrass, longspike tridens
Sumpf clay	giant cutgrass (20%), maidencane (25%), cattail (10%)
Surfside clay	gulf cordgrass (80%), sea-oxeye and other forbs
Tatum clay Loam	smooth cordgrass (90%)
Tracosa mucky clay	smooth cordgrass (90%)
Tracosa mucky clay-clay, low complex	smooth cordgrass (dominant); seashore saltgrass, glasswort, maritime saltwort, saltmarsh bulrush; widgeongrass
Vamont clay	little bluestem (dominant), indiangrass, switchgrass, eastern gamagrass, Florida paspalum, big bluestem, brownseed paspalum, panicum, sedges
Vamont clay, 1 to 4% slopes	mixed pine and hardwoods, sedges, switchgrasses, and bluestem; bermudagrass, dallisgrass
Velasco clay	marshhay cordgrass (60%), seashore saltgrass (15%), seashore paspalum (15%)
Verland silty clay loam	little bluestem (dominant), indiangrass, switchgrass, eastern gamagrass, Florida paspalum, big bluestem, brownseed paspalum, panicum, sedges
Veston Loam	gulf cordgrass (50%), marshhay cordgrass (20%), indiangrass, little bluestem, switchgrass, knotroot bristlegrass in higher areas
Veston loam (Galveston Co.)	*maritime saltwort, shoregrass, glasswort, and sea-oxeye interspersed with barren flat, seashore saltgrass, sea lavender, seepweed, Carolina wolfberry, and eastern baccharis*
Veston silty clay loam	shoregrass (35%), bushy sea-oxeye (10%)

supports a vegetation assemblage composed predominantly of *Spartina patens* and *Distichlis spicata* (table 11). These species were the most frequently encountered during field surveys.

To simplify the discussion of soil types and their relationships to wetland communities, Marsh Rangeland Sites defined by Crenwelge and others (1988) in the soil survey of Galveston County will be used for comparing soils with wetland communities described in this report.

Marsh Rangeland Sites (Crenwelge and others, 1988) include the following sites, or complexes: (1) Salt Marsh Range Site, (2) Tidal Flat Range Site, (3) Salt Flat Range Site, (4) Low Coastal Range Site, (5) Coastal Swale Range Site, (6) Deep Marsh Range Site, (7) Salty Prairie Range Site, and (8) Coastal Sand Range Site.

The Salt Marsh Range Site, with elevations of 1 to 4 ft above sea level, occurs in relatively level coastal marsh areas and in flood plains. It is composed of the Harris clay (Ha and 19), Placedo clay (Pd), and Veston loam, strongly saline (Vx) (table 11). Almost 40 sites, or about 30 percent of all the sites surveyed, corresponded to the Salt Marsh Range Site complex as defined by Crenwelge and others (1988). Based on field survey locations, the wetland communities that were typically found on these soils are brackish-water and salt-water marshes (as mapped by White and others, 1985) (appendix A). These communities make up 70 percent of the survey sites within the Salt Marsh Range. High brackish-water marshes represented 30 percent of the sites. Among the dominant species in high brackish- and high salt-water marshes are *Spartina patens* and *Distichlis Spicata* (table 8).

The Tidal Flat Range Site corresponds to broad coastal tidal marshes at elevations slightly below sea level to about 1 ft above sea level. It consists of the Follet clay loam (Fo), Tatlum clay loam (Ta) and the Tracosa soil in the Caplen-Tracosa complex (Ct), the Tracosa mucky clay (Tm), and the Tracosa mucky clay-clay, low complex (Tx) (table 11). Approximately 15 percent of the field survey sites are located within the the Tidal Flat Range Site. The predominant wetland communities (as defined and mapped by White and others, 1985) are proximal salt-water marshes, which represent about 70 percent of the field survey sites located in the Tidal Flat Range Site. The predominant vegetation is *Spartina alterniflora*; other species may include *Batis maritima, Distichlis spicata, Salicornia* spp., *Scirpus maritimus,* and *Juncus roemerianus.*

The Salt Flat Range Site occurs in nearly level coastal marshes with elevations slightly above mean sea level to about 3 ft above sea level. Soils of this range site are strongly saline Mustang fine sand (Ms) and very strongly saline Veston loam (Vx) (table 11). Sixteen survey sites were located within these soils, or slightly more than 10 percent of all sites surveyed. Wetland communities represented on the Salt Flat Range Site are predominantly salt-water marshes, but some include transitional areas and mixtures of marshes and barren sand flats (White and others, 1985) (appendix A). Vegetation includes *Batis maritima, Monanthochloe littoralis, Salicornia* spp., *Borrichia frutescens, Distichlis spicata, Limonium nashii, Lycium carolinianum,* and others.

The Coastal Swale Range Site occurs in swales between beach ridges and in shallow depressions on nearly level coastal flats. Soils in this range site are principally in the Nass soil of the Galveston-Nass complex (Gc), the Mustang-Nass complex (Mt), and the Nass-Galveston complex shell substratum (Nx). Vegetation communities were surveyed at nine sites corresponding to soils in the Coastal Swale Range Site. The areas surveyed were mostly located on Galveston Island, much of which is characterized by relict beach ridge and swale topography. Vegetation communities are predominantly defined by brackish- and salt-water marshes, both low and high marshes (White and others, 1985). Vegetation includes *Spartina patens, Distichlis spicata, Paspalum vaginatum, Paspalum monostachyum, Monanthochloe littoralis, Spartina spartinae, Juncus roemerianus, Salicornia* spp., and *Borrichia frutescens.*

The Deep Marsh Range Site commonly corresponds with marshes near bays and bayous where tidal-water salinities are lower because of saltwater and freshwater mixing. Elevations range from sea level to 1 ft above. Soils include the Caplen mucky silty clay loam (Ca), and the Caplen soil in the Caplen-Tracosa complex. Dominant vegetation is *Spartina patens* and *Distichlis spicata*. *Spartina cynosuroides* has been a dominant species on this range site in the past, but has been replaced principally by *Spartina patens* (Crenwelge and others, 1988). Depending on water depth and salinities, *Sagittaria* and bulrushes may also occur in this marsh range site. Only a couple of survey sites (high, or distal, salt-water marshes) occur within this range site.

The Salty Prairie Range Site occurs on broad, relatively level coastal flats and marshes, where elevations range from 2 to 8 ft above sea level. Among the soils characterizing this range site is the Ijam soil in the Ijam clay, 0–2 percent slopes (ImA), and 2–8 percent slopes (ImB), Narta fine sandy loam (Na), Sievers loam (SeB), and slightly saline Veston loam (Vx). Most of the survey sites in this range site correspond to the Ijam soils, which might be considered a disturbed soil complex (fig. 29). Ijam soils are formed in saline, clayey, marine and alluvial sediment deposits that were dredged to construct and maintain canals or waterways. Plant communities on these soils vary widely because of the variations in salinities and elevations that characterize this range site. Plant communities may include brackish and salt marshes, barren flats, transitional areas, and uplands. The dominant vegetation in many topographically higher areas is *Spartina spartinae*. Other species may include *Borrichia frutescens*, *Panicum virgatum*, *Spartina patens*, *Phragmites australis*, and *Setaria geniculata*.

The Low Coastal Range Site consists of level to gently sloping coastal sands that roughly parallel the Gulf shoreline; elevations are less than 3.3 m (10 ft) above sea level. Soils in this range site are the Galveston soil in the Galveston-Nass complex (Gc) and Nass-Galveston complex (Nx), and Mustang soils in Mustang fine sand (Mn), Mustang-Nass complex (Mt), and Mustang fine sand, slightly saline (Ms). The Galveston and Mustang soils are at elevations generally too high for marsh development, and therefore, correspond most frequently to uplands (U) and possibly transitional areas as mapped by White and others (1985). Wetlands occur in the Nass soils of the Gc and Nx complexes (see Coastal Swale Range Site).

The Coastal Sand Range Site is composed of nearly level to undulating coastal ridges that parallel the Gulf shoreline. Elevations, which are up to 4 m (12 ft) above mean sea level, preclude marsh development on this range site.

Examples of Wetland Profiles Developed From Topographic Survey Transects

Topographic surveys of marsh communities were conducted at selected sites around the Galveston Bay system. These data are presented in appendix C. Descriptions of the zonation of plant species along two transects are presented here.

Smith Point Transect

The elevation survey of the Smith Point marsh is shown in figure 11. The transect has a bearing of south 45 degrees west (S45°W) and is approximately 85 m (279 ft) long. The southwest end of the transect intersects the shoreline of East Galveston Bay. The total range in elevation of the transect is approximately 1.5 m (5 ft), which is the vertical distance from station 1 (just below the water line) to station 6, the crest of the shell berm. Marsh plants, which are absent on the shell berm, have a much lower range in elevation, about 45 cm (1.5 ft) (fig. 11). This salt marsh community, which is classified as an estuarine intertidal emergent community (E_2EM) as

Figure 29. Disturbed-area community on a small spoil mound along the Intracoastal Waterway on the landward margin of Follets Island. A mixed assemblage of approximately 10 salt-marsh species occurs on the mound. Species range from *Iva frutescens* and *Spartina spartinae* at the top, to *Batis* and *Salicornia* at the base. Site No. 1-2, Freeport Quad. (This Quad is not officially part of the project area).

defined by Cowardin and others (1979), is made up of about 8 different species. *Spartina alterniflora* (smooth cordgrass), as expected, occurs at the lowest elevation (water line), and a community composed of *Spartina spartinae* (gulf cordgrass or sacahuista), *Spartina patens* (marshhay cordgrass), *Iva frutescens* (bigleaf sumpweed or marshelder), and *Borrichia frutescens* (sea-oxeye) occurs at the highest elevation (stations 18 and 19, fig. 11). The profile exemplifies how small changes in elevation along the microtidal Texas coast can affect plant distribution. Occurring at elevations between the water line and the highest marsh plants on the profile are several species (fig. 11) including, at lower elevations, *Scirpus maritimus* (salt-marsh bulrush) and *Juncus roemerianus* (needlegrass rush); at slightly higher elevations *Distichlis spicata* (seashore saltgrass) occurs. *Spartina patens* and *Borrichia* also occur at intermediate elevations, but are still higher than *Spartina alterniflora, Scirpus, Juncus*, and *Distichlis*. The range in elevation for *Spartina alterniflora* is about 25 cm (0.8 ft) along this transect, so it occurs mixed with other species locally.

A close look at the profile (fig. 11) shows that very small changes in elevation can apparently increase the regularity of flooding and enable species like *Spartina alterniflora* to become established. Stations 10 and 14 have *Spartina alterniflora* mixed with *Distichlis*. At slightly higher elevations toward station 12, only *Distichlis* is present.

This particular survey shows that, in general, the species occurring at lowest (and therefore most frequently flooded) elevations are *Spartina alterniflora, Scirpus maritimus*, and *Juncus roemerianus*, with *Distichlis* mixing with these species locally. Occurring at higher elevations are *Spartina patens, Borrichia, Spartina spartinae*, and *Iva frutescens*.

Wetland indicator plant species designations in the *National List of Plant Species that Occur in Wetlands: 1988 Texas*, by P. B. Reed, USFWS, were used as a guide to help delineate species associations in some areas. Species identified along the Smith Point profile are all wetland species, but *Spartina alterniflora, Scirpus maritimus*, and *Juncus roemerianus* are classified as obligate (OBL) wetland plants, which means that under natural conditions they have an estimated probability of occurring in wetlands greater than 99 percent of the time. The other species listed above (i.e., those occurring at slightly higher and drier elevations) are facultative wetland (FACW) plants, which means that they usually occur in wetlands (estimated probability of 67 to 99 percent), but occasionally are found in nonwetlands. As expected, the elevation measurements properly defined the species that can tolerate wetter conditions and are therefore more frequently found in wetlands.

Brazoria National Wildlife Refuge Transect

The second salt marsh transect along which elevations, distances, and bearings were measured was located in the Brazoria National Wildlife Refuge (fig. 12). The transect, which is approximately 375 m (1,230 ft) long, is oriented roughly perpendicular to the hydrologic gradient and was tied to a USGS bench mark with an elevation of 2.2 m (6.6 ft) at the northwest end of the transect. Lower elevations occur on the downthrown side of a fault located at stations 4 and 5 on the profile (fig. 12). The difference in elevations on each side of the fault line produces a dramatic effect in the vegetation communities. Between the bench mark and station 4 at the edge of the fault (this segment of the transect marks the upthrown side of the fault) the plant community is dominated by *Spartina spartinae*, with scattered species including *Setaria geniculata* (knotroot bristlegrass), *Iva annua* (seacoast sumpweed), and *Aster* spp. Additional species reported in this area in the Brazoria County Soil Survey include *Nothoscordum bivalve* (false garlic) and *Sabatia campestris* (prairie rose-gentian). The dominant species *Spartina spartinae* is classified as a faculative wetland (FACW), but other species, except for *Aster* (OBL), are found much less frequently in wetlands. *Iva annua* and *Setaria* are classified as facultative

(FAC), and are, therefore, equally likely to occur in nonwetlands as wetlands. *Sabatia* and *Nothoscordum* are classified as facultative upland species (FACU), which means the probability of their occurring in a wetland is only 1 to 33 percent.

On the downthrown side of the fault, a definite wetland community occurs. The drop in elevation from the top of the fault scarp to the wetland community is more than 30 cm (1 ft). Plant species between stations 5 and 6 (fig. 12) on the profile are composed of patches of *Monanthochloe, Salicornia,* and *Batis* occurring within a sand/mud flat that is capped by an algal mat. At lower elevations, between stations 6 and 7, *Distichlis* composes about 90 percent of the community, with scattered *Salicornia* making up the remaining 10 percent. All the species on the downthrown side of the fault, where wetter conditions characterize the lower elevations, are obligate wetlands.

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